भारतीय मानक
Indian Standard

IS 15916 : 2020

पूर्व संविचरित कंक्रीट प्रयुक्त भवन का डिजाइन और स्थापन — रीति संहिता

(पहला पुनरीक्षण)

Building Design and Erection Using Prefabricated Concrete — Code of Practice

(First Revision)

ICS 91.040.01

© BIS 2020

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुरशाह ज़फर मार्ग, नई दिल्ली – 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002
www.bis.gov.in www.standardsbis.in

December 2020 **Price Group 14**

Planning, Housing and Prefabricated Construction Sectional Committee, CED 51

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Planning, Housing and Prefabricated Construction Sectional Committee had been approved by the Civil Engineering Division Council.

Prefabrication, though desirable for large scale building activities, is now gaining importance for use in the country. Two aspects of prefabrication, specifically to be borne in mind, are the system to be adopted for the different categories of buildings and the sizes of their components. Here the principle of modular coordination is of value and its use is recommended.

Advantages of recent trends in prefabrication have been taken note of and also the hazards attended to such construction. Recommendations on the need to avoid progressive collapse of the structure are covered to make a structure reasonably safe against such a collapse.

Since the aim of prefabrication is to effect economy and improve quality and speed of construction, the selection of proper materials for prefabrication is also an important factor in the popularization of this technique. The use of locally available materials with required characteristics and those materials which, due to their innate characteristics, such as lightweight, easy workability, thermal insulation, non-combustibility, etc, effect economy and improve quality may also be tried. However, this standard pertains to prefabricated elements with cementitious materials.

It is possible to achieve or evolve aesthetically satisfying designs using prefabricated construction. A careful and judicious handling of materials and use of finishes on a prefabricated building can help the designer a great deal in ensuring that the appearance of the building is aesthetically appealing. The purpose of finishes and architectural treatment is not only to give prefabricated buildings an individual character but also to effect better performance and greater user satisfaction.

This standard was first published in 2010 to provide necessary guidance for design and erection of prefabricated concrete buildings.

This revision of the standard has been taken up to incorporate various changes found necessary as a result of experience gained and technological advances made in the field of prefabricated construction.

In this revision the following major modifications have been incorporated:

a) Definitions of some new terms have been added and existing terminologies modified, wherever required.
b) False joints have been explained.
c) Provisions relating to prefabricated systems have been updated.
d) Provisions for precast components have been updated. Casting tolerance for length of column and stair unit have been modified.
e) Provisions on precast filigree slab panel have been included.
f) Provisions on box-type construction have been updated.
g) Detailed provisions on diaphragm action of floor systems have been included.
h) Emulative system has been categorized and detailed with respect to its definition, analysis, design, detailing, etc.
j) Design considerations have been updated where accidental impact due to vehicles has been included.
k) Provisions to ensure stability of precast wall panel during erection have been updated.
m) Typical figures for connection of peripheral ties have been added.
n) Provisions on vertical joints have been updated.
p) Provisions and testing procedures for water tightness of joints have been included.
q) Provisions on mould for manufacture of precast elements have been updated.
r) Provisions relating to fire resistance testing of prototypes under sustained load has been provided for.

(*Continued to third cover*)

Indian Standard

BUILDING DESIGN AND ERECTION USING PREFABRICATED CONCRETE — CODE OF PRACTICE

(First Revision)

1 SCOPE

This standard covers provisions regarding modular planning, component sizes, prefabrication systems, design considerations, joints and manufacture, storage, transportation and erection of prefabricated concrete elements for use in buildings and such related requirements for prefabricated concrete.

2 REFERENCES

The standards and special publication listed in Annex A contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated in Annex A.

3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

3.1 Authority Having Jurisdiction — The authority which has been created by a statute and which, for the purpose of administering the standard, may authorize a committee or an official or an agency to act on its behalf; hereinafter called the 'Authority'.

3.2 Basic Module —The fundamental module used in modular coordination, the size of which is selected for general application to building and its components.

NOTE — The value of the basic module has been chosen as 100 mm for the maximum flexibility and convenience. The symbol for the basic module is *M*.

3.3 Cellular Concrete — The material consisting of an inorganic binder (such as, lime or cement or both) in combination with a finely ground material containing siliceous material (such as sand), gas generating material (for example, aluminium powder), water and harmless additives (optional); and/or steam cured under high pressure in autoclaves.

3.4 Components — A building product formed as a distinct unit having specified sizes in three dimensions.

3.5 Composite Members — Structural members comprising prefabricated structural units of steel, pre-stressed concrete or reinforced concrete and cast *in-situ* concrete connected together in such a manner that they act monolithically.

3.6 Diaphragm — It is a horizontal or nearly horizontal structural system (for example, reinforced concrete floors and horizontal bracing systems), which transmits lateral forces to vertical elements that resist earthquake-induced inertia effects.

3.7 Emulative Detailing System — A connection detailing system for precast concrete structures that has structural performance equivalent to that of a conventionally designed, cast *in-situ*, monolithic concrete structure.

3.8 False Joints — Architecutural reveals that are used to build aesthetic patterns on the elevations or around the physical precast joint patterns as per structural framing (*see* Fig. 1).

3.9 Increments — Difference between two homologous dimensions of components of successive sizes.

3.10 Jointed Detailing System — A connection detailing system for precast concrete/cast *in-situ* and precast concrete component structures that have individual precast components separated from each other but connected using special connections such as welded or bolted plates.

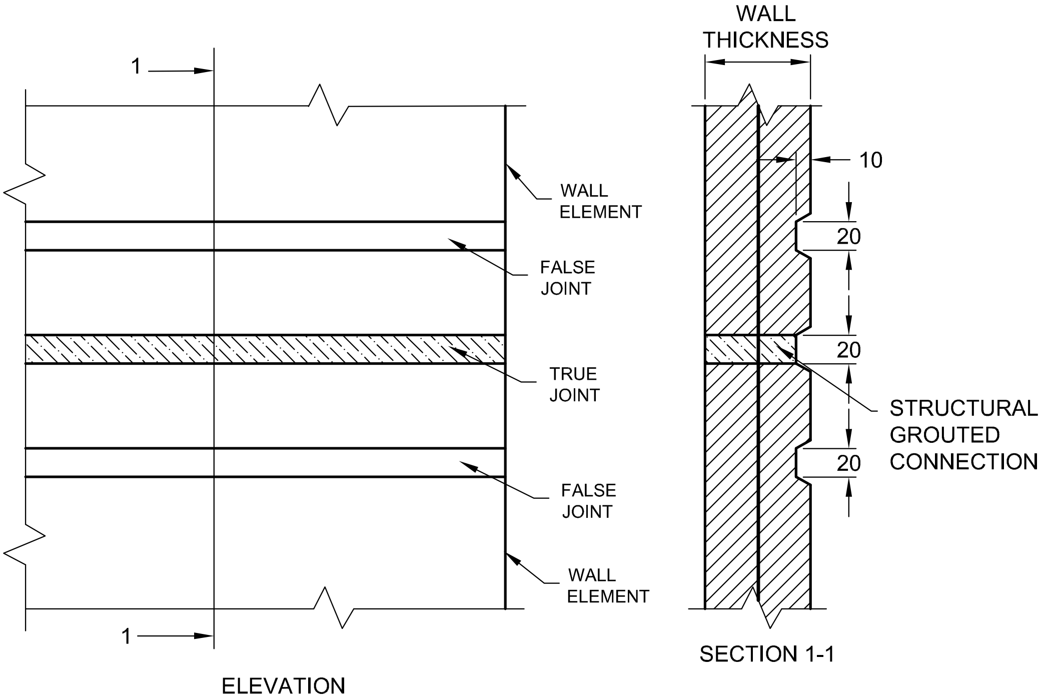
3.11 Light Weight Concrete — Concrete of substantially lower unit weight than that made from gravel or crushed stone.

3.12 Module — A unit of size used in dimensional coordination.

3.13 Modular Coordination — Dimensional coordination employing the basic module or a multimodule.

NOTE — The purposes of modular coordination are to,

a) reduce the variety of component sizes produced; and
b) allow the building designer greater flexibility in the arrangement of components.



All dimensions in millimetres.

FIG. 1 TYPICAL TRUE JOINT AND FALSE JOINT PRECAST WALL ELEMENT

3.14 Modular Grid — A rectangular coordinate reference system in which the distance between consecutive lines is the basic module or a multimodule. This multimodule may differ for each of the two orthogonal directions of the grid.

3.15 Multimodule — A module whose size is a selected multiple of the basic module.

3.16 Prefabricate — To fabricate components or assembled units (on site or off site) prior to erection or installation in a building.

3.17 Prefabricated Building — The partly/fully assembled and erected building, of which the structural parts consist of prefabricated individual units or assemblies using ordinary or controlled materials, including service facilities; and in which the service equipment may be either prefabricated or constructed *in-situ*.

3.18 Sandwich Reinforced Concrete Panels — Panels made by sandwiching an insulation material between two layers of reinforced/prestressed concrete to act as insulation for concrete panels.

3.19 Self Compacting Concrete — Concrete that is able to flow under its own weight and completely fill the voids within the formwork, even in the presence of dense reinforcement without any vibration, whilst maintaining homogeneity without segregation.

3.20 Shear Connectors — Structural elements, such as anchors, studs, channels, loops and spirals intended to transmit the shear between the prefabricated member and the cast *in-situ* concrete, and also to prevent separation at the interface.

3.21 System — It is a particular method of construction of buildings with certain order and discipline using the prefabricated components which are inter-related in functions and are produced based on a set of instructions.

3.22 Unit — Building material formed as a simple article with all three dimensions specified, complete in itself but intended to be part of a compound unit or complete building. Examples are brick, block, floor panel, wall panel, beams, columns, etc.

4 MATERIALS, PLANS AND SPECIFICATIONS

4.1 Materials

Use of materials for plain, reinforced concrete and pre-stressed concrete shall satisfy the requirements of IS 456 and IS 1343. Connections and jointing materials shall be in accordance with **9.3**.

4.1.1 While selecting the materials for prefabrication, the following characteristics shall be considered:

a) Easy availability;

b) Light weight for easy handling and transport;

c) Strength;
d) Thermal insulation property;
e) Easy workability;
f) Minimal water absorption;
g) Serviceability along with durability;
h) Non-combustibility/fire resistance rating;
j) Sound insulation;
k) Easy assembly and compatibility to form a complete unit;
m) Economy; and
n) Any other special requirement in a particular application.

4.2 Plans and Specifications

The detailed plans and specifications shall cover the following:

a) Such drawings shall describe the elements and structure, and assembly including all required data of physical properties of component materials, material specification, strength of concrete for demoulding, casting/erection tolerance and type of curing to be followed.
b) Details of connecting joints of prefabricates or precast concrete and cast *in-situ* components shall be given to an enlarged scale.
c) Site or shop location of services, such as installation of piping, wiring or other accessories integral with the total scheme shall be shown separately.
d) Data sheet indicating the location of the inserts and acceptable tolerances for supporting the prefabricate during erection, location and position of doors/windows/ventilators, etc, if any.
e) The drawings shall also clearly indicate location of handling arrangements for lifting and handling the prefabricated elements, sequence of erection with critical check points and measures to avoid stability failure during construction stage of the building.

5 MODULAR COORDINATION, ARCHITECTURAL TREATMENT AND FINISHES

5.1 Modular Coordination

The basic module shall be adopted. After adopting this, further work is necessary to outline suitable range of multi modules with greater increments, often referred to as preferred increments. A set of rules as detailed below would be adequate for meeting the requirements of conventional and prefabricated construction.

These rules relate to the following basic elements:

a) The planning grid in both directions of the horizontal plan shall be:
    1) 15 *M* for industrial buildings, and
    2) 3 *M* for other buildings.

    The centre lines of load bearing walls should preferably coincide with the gridlines.
b) The planning module in the vertical direction shall be 2 *M for* industrial buildings and 1 *M* for other buildings.
c) Preferred increments for sill heights, doors, windows and other fenestration shall be 1 *M*.
d) In the case of internal columns, the grid lines shall coincide with the centre lines of columns. In case of external columns and columns near the lift and stair wells, the grid lines shall coincide with centre lines of the column in the topmost storey.

5.2 Architectural Treatment and Finishes

5.2.1 In general, prefabricated systems provide better opportunity to achieve superior finishes leading to an array of aesthetically pleasing options. The architectural elevational treatments form and features can also be effectively incorporated in the structures with careful advanced planning. In addition, detailed coordination between the architectural and structural design team during the planning stage for panel joints and false joints is necessary. The purpose of finishes and architectural treatment is not only to give prefabricated buildings an individual character but also to effect better performance and greater user satisfaction.

5.2.2 Treatment and finishes have to be specified keeping in view the requirements of protection, function and aesthetics of internal and external spaces and surfaces.

5.2.3 While deciding the type of architectural treatment and finishes for prefabricated buildings, the following points should be kept in view:

a) Suitability for mass production techniques;
b) Recognition of the constraints imposed by the level of workmanship available;
c) Possibility of using different types of finishes;
d) Use of finishes and architectural treatment for the creation of a particular architectural character in individual buildings and in groups of buildings by the use of colour, texture, projections and recesses on surfaces including form liners, etc;
e) Incorporation of structural elements like joists, columns, beams, etc, as architectural features and the treatment of these for better overall performance and appearance;
f) Satisfactory finishing of surfaces keeping in view the life cycle performance; and
g) Use of lightweight materials to effect economy in the structural system.

5.2.4 Some of the acceptable methods of finishes integral with the pre-casting are:

1) Concrete surface moulded to design/shape;
2) Laid-on finishing tiles fixed during casting;
3) Finishes obtained by washing, tooling, grinding, grooving of hardened concrete;
4) Exposed aggregates; and
5) Other integral finishes.

6 COMPONENTS

6.1 The dimensions of precast elements shall meet the design requirements. However, the actual dimensions shall be the preferred dimensions as follows:

a) *Flooring and roofing scheme* — Precast slabs or other precast structural flooring units:
   1) *Length* — Nominal length shall be in multiples of 1 *M*;
   2) *Width* — Nominal width shall be in multiples of 0.5 *M*; and
   3) *Overall thickness* — Overall thickness shall be in multiples of 0.1 *M*.

b) *Beams*:
   1) *Length* — Nominal length shall be in multiples of 1 *M*;
   2) *Width* — Nominal width shall be in multiples of 0.1 *M*; and
   3) *Overall depth — Overall depth of the floor zone shall be in multiples of* 0.1 *M.*

c) *Columns:*
   1) *Height* — Height of columns for industrial building *and other* buildings shall be in multiples of 1 *M,* and
   2) *Lateral dimensions* — Overall lateral dimension or diameter of columns shall be in multiples of 0.1 *M*.

d) *Walls:*

   Thickness — The nominal thickness of walls shall be in multiples of 0.1 *M*.

e) *Staircase:*

   Width — Nominal width shall be in multiples of 1 *M*.

f) Lintels:
   1) *Length* — Nominal length shall be in multiples of 1 *M*;
   2) *Width* — Nominal width shall be in multiples of 0.1 *M*; and
   3) *Depth* — Nominal depth shall be in multiples of 0.1 *M*.

g) *Sunshades/Chajja Projections* :
   1) *Length* — Nominal length shall be in multiples of 1 *M*.
   2) *Projection* — Nominal length shall be in multiples of 0.5 *M*.

NOTE — *M* is the basic module.

6.2 Casting Tolerances of Precast Components

The casting tolerances of various precast components shall be as given below:

Sl No. (1)	*Product Tolerances* (2)	*Product (see Key No.)* (3)
Key No. for product reference:		
1 Channel unit		
2 Ribbed slab unit/hollow slab		
3 Waffle unit		
4 Large panel prefabrication and box unit prefabrication		
5 Cellular concrete floor/roof slabs		
6 Prefabricated brick panel		
7 Precast planks		
8 Ribbed/plain wall panel		
9 Column		
10 Stair unit:		
i)	Length:	
	a) ± 5 mm	1, 7
	b) ± 5 mm or ± 0.1 percent, whichever is greater	2, 3, 8
	c) ± 0.1 percent subject to maximum of $^{+5}_{-10}$ mm	4

Sl No.	*Product Tolerances*	*Product (see Key No.)*
(1)	(2)	(3)
	d) 1) ± 2 mm for length below and up to 500 mm 2) ± 5 mm for length over 500 mm	5
	e) ± 10 mm	6
	f) ± 8 mm	9, 10
ii)	Thickness/Cross-sectional dimensions:	
	a) ± 3 mm	1
	b) ± 3 mm or 0.1 percent, whichever is greater	2, 8
	c) 1) ± 2 mm upto 300 mm wide 2) ± 3 mm greater than 300 mm wide	4, 5
	d) ± 2 mm	3, 7
	e) ± 4 mm	6, 9, 10
iii)	Straightness/Bow:	
	a) ± 5 mm or 1/750 of length, whichever is greater	2, 4, 8
	b) ± 3 mm	1, 5
	c) ± 2 mm	7
iv)	*Squareness* – When considering the squareness of the corner, the longer of two adjacent sides being checked shall be taken as the base line, and the following tolerances shall apply:	
	a) The longer side shall not vary in length from the perpendicular by more than 5 mm	2, 5, 8
	b) The shorter side shall not vary in length from the perpendicular by more than 3 mm	1, 7
	c) The shorter side shall not be out of square line for more than $^{+2}_{-5}$ mm	4
v)	*Twist* – Any corner shall not be more than the tolerance given below from the plane containing the other three corners:	
	a) 1) Up to 600 mm, in width and up to 6 m, in length 5 mm 2) Over 600 mm, in width and for any length 10 mm	2, 8
	b) ± 1/1 500 of dimension or ± 5 mm, whichever is less	4
	c) ± 3 mm	1
	d) ± 1 mm	7
vi)	*Flatness* – The maximum deviation from 1.5 m straight edge placed in any position on a nominal plane surface shall not exceed:	
	a) ± 5 mm	2, 8
	b) ± 3 mm	4
	c) ± 2 mm	1, 7
	d) ± 4 mm or maximum of 0.1 percent length	5

The structural supporting elements shall be designed/checked for stability and design adequacy for the above mentioned tolerance limits. All formwork shall be designed to give exact dimension, well within the tolerances given above.

7 PREFABRICATION SYSTEMS AND STRUCTURAL SCHEMES

7.1 The word ‘system’ refers to a particular method of construction of buildings using the prefabricated components which are inter-related in functions and are produced to a set of instructions. With certain constraints, several plans are possible using the same set of components. The degree of flexibility varies from system to system. However, in all the systems there is a certain order and discipline.

7.2 The following aspects, among others, are to be considered in devising a system:

a) Effective utilization of spaces;
b) Straight and simple walling scheme;
c) Limited sizes and numbers of components;
d) Limited opening in bearing walls;
e) Regulated locations of partitions;
f) Standardized service and stair units;
g) Limited sizes of doors and windows with regulated positions;
h) Structural clarity and efficiency;
j) Suitability for adoption in low rise and high rise building;
k) Ease of manufacturing, storing and transporting;
m) Speed and ease of erection;
n) Effective utilization of available equipment, plant and machinery; and
p) Simple jointing system.

7.3 Prefabrication Systems

The system of prefabricated construction depends on the extent of the use of prefabricated components, their materials, sizes and the technique adopted for their manufacture and use in building.

7.3.1 *Types of Prefabrication Components*

The prefabricated concrete components, such as those given below may be used which shall be in accordance with relevant Indian Standards, such as IS 2185 (Parts 1 to 4), IS 3201, IS 6072, IS 6073, IS 9893, IS 10297, IS 10505, IS 11447, IS 12440, IS 13990, IS 14143, IS 14201 and IS 14241, where available:

1) Reinforced/pre-stressed concrete channel unit,
2) Reinforced/pre-stressed concrete slab unit,
3) Reinforced/pre-stressed concrete beams,
4) Reinforced/pre-stressed concrete columns,
5) Reinforced/pre-stressed concrete hollow core slab,
6) Reinforced concrete waffle slab/shells,
7) Reinforced/pre-stressed concrete wall elements,
8) Hollow/solid concrete blocks and battens,
10) Precast planks and joists for flooring and roofing,
11) Precast joists and trussed girders,
13) Light weight/cellular concrete slabs/wall panels,
14) Precast lintel and *Chajjas*,
16) Large panel prefabricates and box units,
17) Reinforced/prestressed concrete trusses,
18) Reinforced/prestressed roof purlins,
19) Precast concrete L-panel unit,
20) Prefabricated concrete double-T unit,
21) Prefabricated brick panel unit,
23) Prefabricated sandwich concrete panels,
25) Precast concrete foundation,
26) Precast concrete staircase, and
27) Filigree slab or precast composite slab (lattic girder slab).

There may be other types of components which may be used with the approval of the Authority.

NOTE — The elements may be cast at the site or off the site.

7.3.2 *Open Prefabrication System*

There are two categories of open prefab system depending on the extent of prefabrication used in the construction as given in **7.3.2.1** and **7.3.2.2**.

7.3.2.1 *Partial prefabrication system*

In this system part of the structural components are precast and remaining are cast *in-situ* based on design approach of required structural integrity and ease of manufacturing process. This system basically uses precast roofing and flooring components and other minor elements like lintels, *Chajjas*, kitchen sills in conventional building construction. The structural system could be in the form of *in-situ* framework or load bearing walls.

7.3.2.2 *Full prefabrication system*

In this system almost all the structural components are prefabricated. The filler walls may be of brick/block masonry, precast RCC concrete panel units or any other locally available material.

7.3.3 *Large Panel Prefabrication System*

This system is based on the use of large prefab components. The components used are precast concrete large panels for walls, floors, roofs, balconies, staircases, etc. The casting of the components could be at the site or off the site.

Depending upon the extent of prefabrication, this system can also lend itself to partial prefab system and full prefab system.

Structural scheme with precast large panel walls can be classified as given in **7.3.3.1** to **7.3.3.3**.

7.3.3.1 *Precast walls*

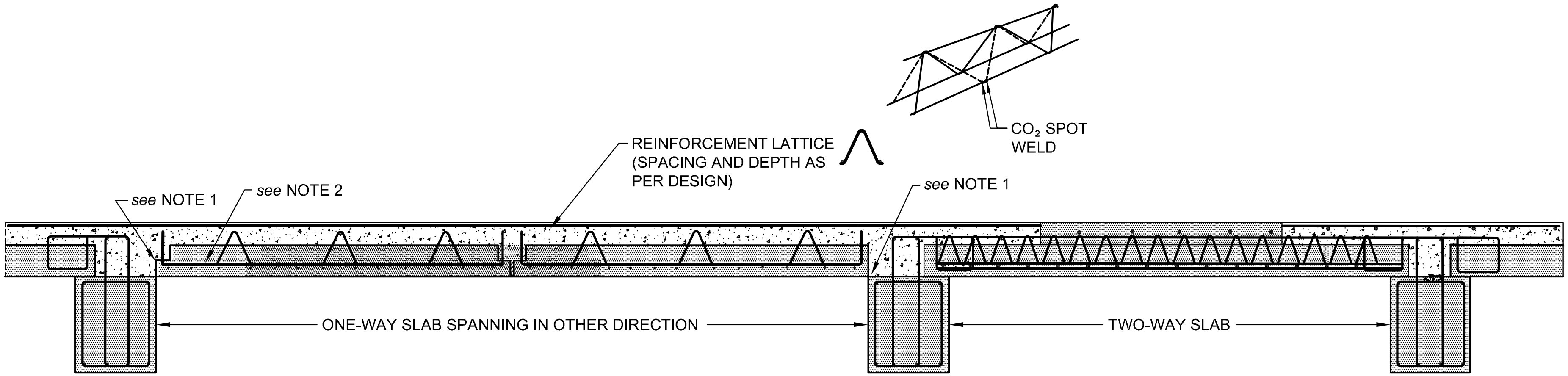
a) Based on the structural functions of the walls, the precast walls may be classified as:
   1) Load bearing walls,
   2) Non-load bearing walls, and
   3) Shear walls.
b) Based on construction, the precast walls may be classified as:
   1) *Homogeneous walls* — Which could be solid, hollow or ribbed; and
   2) *Non-homogeneous walls,* — These could be composite or sandwich panels.
c) Based on their locations and functional requirements, the precast walls may also be classified as:
   1) External walls, which may be load bearing or non-load bearing depending upon the layout. These are usually homogenous but sometimes non-homogeneous sandwiched type to impart better thermal comfort. They can also act as shear walls to resist horizontal loads with appropriate design; and
   2) Internal walls providing resistance against vertical loads, horizontal loads, fire, etc. These are normally homogeneous walls.

7.3.3.2 *Precast floors*

a) Depending upon the composition of units, precast flooring units may be classified as:
   1) *Homogeneous floors* — These may be of solid slabs, cored slabs, ribbed or waffle slabs and precast slabs with structural topping designed as a composite system. A minimum structural topping of 75 mm concrete with reinforcing mesh shall be used in seismic zones III, IV and V, which can be reduced to 50 mm in seismic zone II.
   2) *Non-homogeneous floors* — These may be of multi-layered units with combinations of light weight concrete or reinforced/pre-stressed concrete with filler blocks and structural topping.
b) Depending upon the way the loads are transferred, the precast floors may be classified as one-way, two-way or cantilever systems:
   1) One-way system transfers loads to supporting members in one direction only. The precast elements which come under this category are channel slabs, hollow core slabs, channels and ties system, light weight/cellular concrete slabs, etc.
   2) Two-way system transfers loads in both the directions imparting loads on the four edges. The precast elements under this category are room sized panels, two-way ribbed or waffle slab systems, etc.
   3) Cantilever components are supported on one edge or two adjacent edges and other ends without supports.

7.3.3.2.1 *Filigree slab*

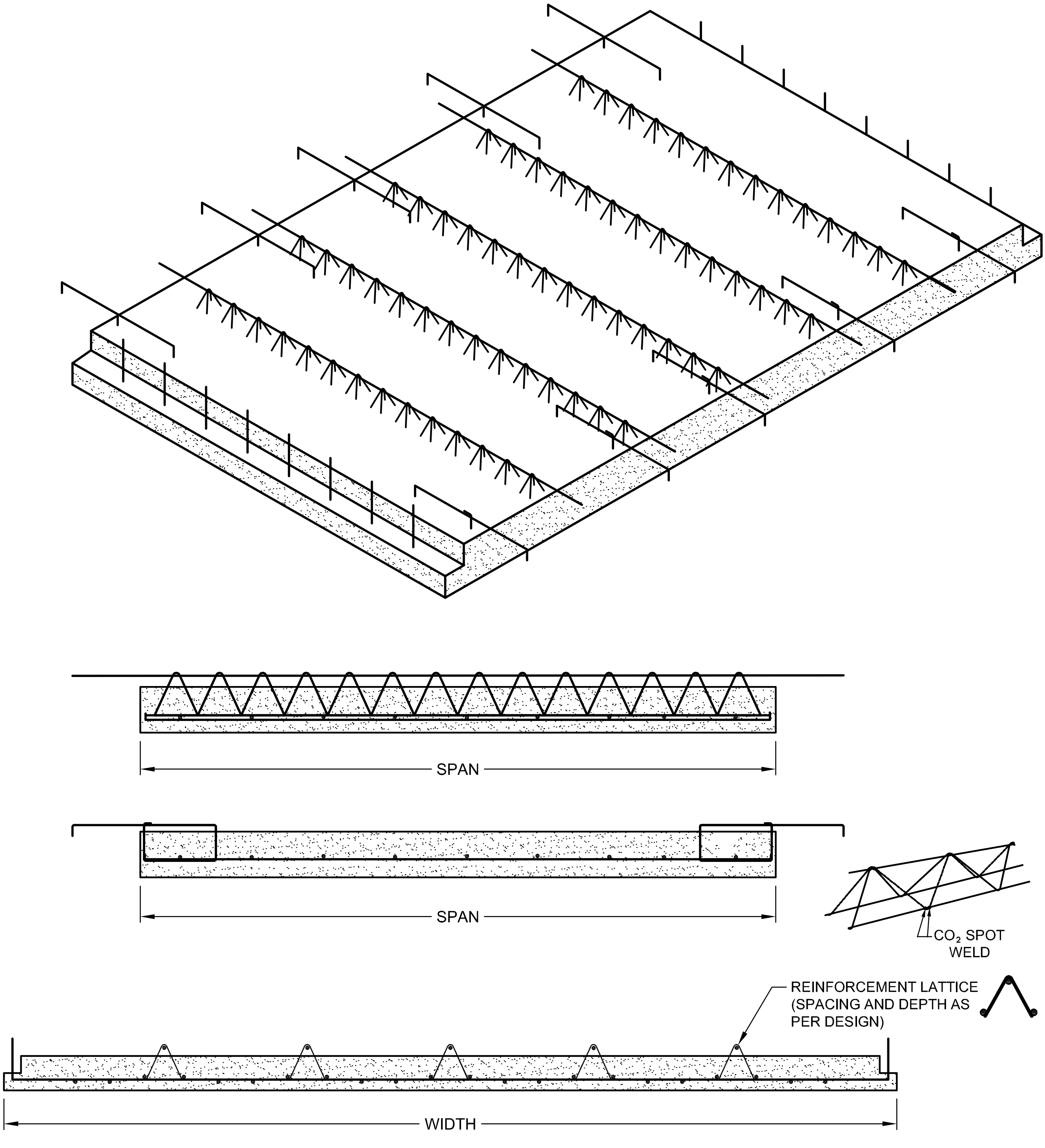
Filigree slab, also termed as half slab or lattice girder slab is a precast composite slab; cast in two stages. The first stage is to manufacture thin precast concrete panels, typically of about 60 mm to 85 mm thick, with the slab's bottom reinforcement and reinforcement lattice girders included. About half the depth of lattice girders project above thin precast concrete panels; which facilitates for multiple point lifting/handling as well as acts as shear connectors for *in-situ* deck concreting laid over precast panels after erection. The slab concrete panels can be designed for overall thickness (precast and *in-situ* deck) as one-way or two-way in accordance with provisions of IS 456, IS 1893 (Part 1), IS 13920 and this standard. On maturity of concrete panels, they are taken to jobsite and erected on beams/walls. Few temporary supports may be necessary depending on span. Subsequently, the deck's top reinforcement is placed on top of precast filigree slabs and concrete is poured over the entire assembly to achieve the final thickness of the deck (*see* Fig. 2). The soffits of the panels have a smooth uniform finish as a result of casting them in polished steel pallets.


CO$_2$ SPOT WELD
REINFORCEMENT LATTICE (SPACING AND DEPTH AS PER DESIGN)
see NOTE 1
see NOTE 2
see NOTE 1
ONE-WAY SLAB SPANNING IN OTHER DIRECTION
TWO-WAY SLAB

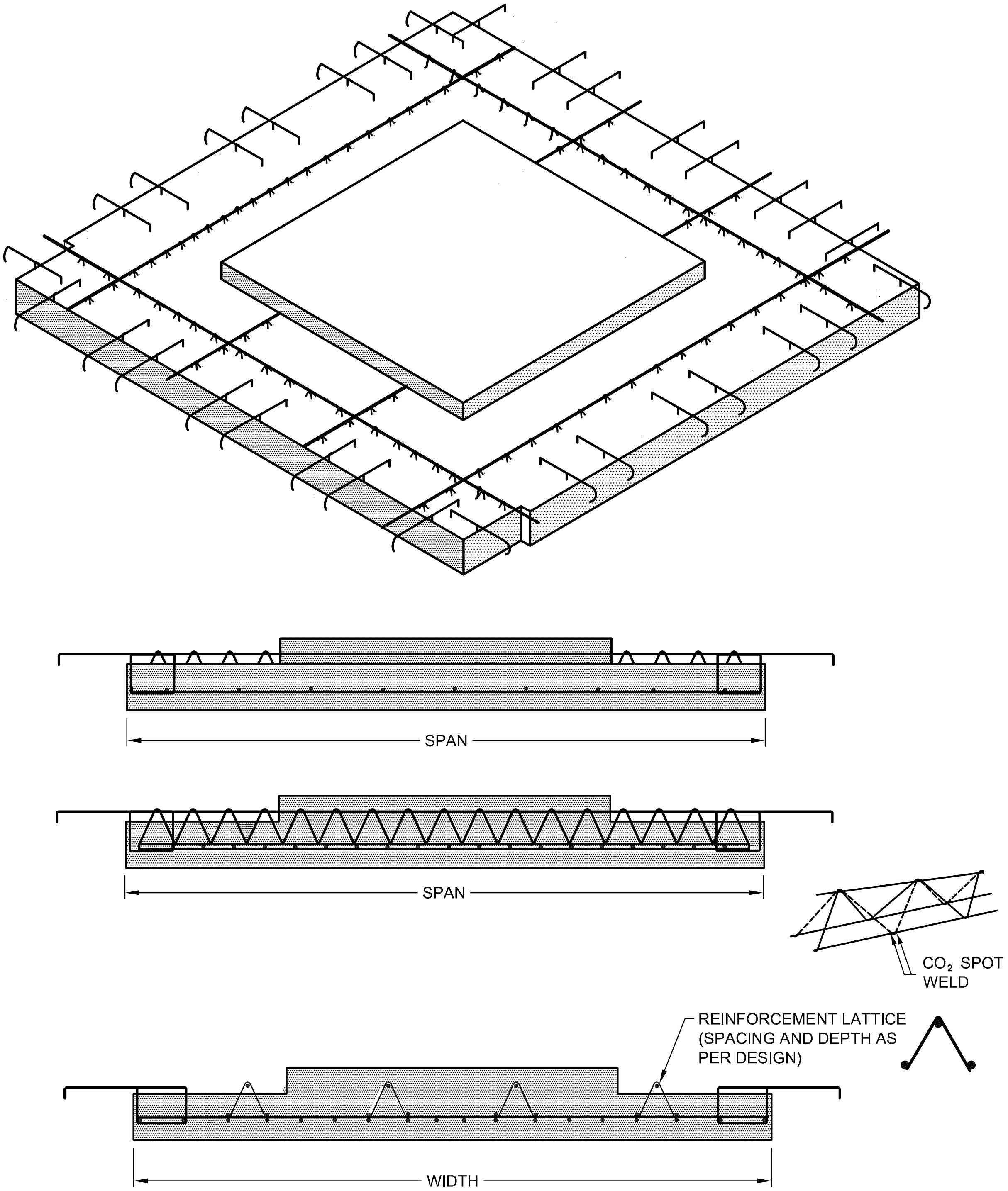
NOTE 1 - BEARING IS OPTIONAL BEING SPANNING IN OTHER DIRECTION

NOTE 2 - THIS REINFORCEMENT SHALL BE DISTRIBUTED UNIFORMLY FOR ENTIRE WIDTH

2A TYPICAL LONGITUDINAL SECTION OF ONE-WAY AND TWO-WAY PRECAST FILIGREE SLAB



2B ONE-WAY PRECAST FILIGREE SLAB PANEL



2 C TWO-WAY PRECAST FILIGREE SLAB PANEL

Fig. 2 Precast Filigree Slab Panel

NOTE — This process can effectively accelerate the construction of structures by eliminating the need for costly and time-consuming field forming, and the placing of bottom reinforcement.

7.3.3.3 *Staircase systems*

Staircase system may consist of flights with in-built risers and treads in the element. The flights are normally unidirectional transferring the loads to supporting landing beams/slabs or load bearing walls.

7.3.4 *Box Type Construction*

In this system, room size units are prefabricated, either in 3D volumetric mould or 2D elements cast at the factory and connected together to construct a 3D box element at the factory and erected at site. Toilet and kitchen blocks may also be similarly prefabricated and erected at site.

NOTE — This system derives its stability and stiffness from the box units which are formed by four adjacent walls. Walls are jointed to make rigid connections among themselves. The box unit rests on foundation, conventional or precast.

8 DESIGN CONSIDERATIONS AND REQUIREMENTS

8.1 Design Considerations

8.1.1 Precast structures could be analyzed either as an emulative systems or as a jointed system. However, emulative analysis is typically preferred where the structure is detailed such that the overall behaviour of the building in its service life will be similar to a reinforced cement concrete building constructed *in-situ*. In emulative approach, the precast structure is analyzed as a monolithic one and the joints in these designed to take the forces of an equivalent discrete system. Resistance to horizontal loading shall be provided by having appropriate moment and shear resisting joints or placing shear walls (in diaphragm braced frame type of construction) in two directions at right angles or otherwise. No account is to be taken of rotational stiffness, if any, of the floor-wall joint in case of precast bearing wall buildings. The individual components shall be designed, taking into consideration the appropriate end conditions and loads at various stages of construction. The components of the structure shall be designed for loads and reactions in accordance with IS 875 (Parts 1 to 5) and IS 1893 (Part 1). In addition, members shall be designed for handling, erection and impact loads that might be expected during handling and erection.

NOTE — Rotational stiffness can be accounted for long/short term deflection calculations, provided that the approach is mutually agreed by the design team and approved by the Authority.

8.1.2 In some conventional forms of construction, experience has shown that structures are capable of safely sustaining abnormal conditions of loading and remaining stable after the removal of primary structural members. It has been shown that some forms of building structure and particularly some industrialized large panel systems have little reserve strength to resist forces not specifically catered for in the design. In light of this, therefore, recommendations made in **8.1.3** to **8.1.10** should be kept in mind for ensuring stability of such prefabricated structures, whether large panel or not.

8.1.3 Adequate strengthening of external joints of external wall panels is important since these elements are not fully restrained on both sides by floor panels. Adequate design precautions may be taken by the designer. External wall panel connections are likely to be the weakest points of a precast panel building, if not designed properly.

8.1.4 It is equally important to provide restraint to all load bearing elements at the corners of the building. These elements and the external ends of cross-wall units should be stiffened either by introducing columns as connecting units or by jointing them to non-structural wall units which in emergency may support the load. Jointing of these units should be done bearing in mind the need for load support in an emergency.

8.1.5 In prefabricated construction, the possibility of gas or other explosions which can remove primary structural elements leading to progressive collapse of the structure shall be taken into account. It is, therefore, necessary to consider the possibility of progressive collapse in which the failure or displacement of one element of a structure causes the failure or displacement of another element and results in the partial or total collapse of the building.

8.1.6 Provision in the design to reduce the probability of progressive collapse is essential in buildings of height more than 15 m and is of relatively higher priority than for buildings of lower height.

One way of preventing progressive collapse of external wall panels is to design the combined precast wall panels of entire width as a beam of depth equal to the floor height for the impact loading of upper floors and provide reinforcement accordingly at the top and bottom of all precast wall panels at each floor. To make reinforcement continuous across joints, top and bottom bars projected into joints between wall panels should be joined with lapping bars.

8.1.7 It is necessary to ensure that any local damage to a structure does not spread to other parts of the structure remote from the point of mishap and that the overall stability is not impaired, but it may not be necessary to stiffen all parts of the structure against local damage or collapse in the immediate vicinity of a mishap, unless the design briefs specially require this to be done. The requirements as specified at **8.2** shall be followed to prevent progressive collapse of the structure.

8.1.8 Additional protection may be required in respect of damage from vehicles. Further, it is necessary to consider the effect of damage to or displacement of a load-bearing member by an uncontrolled vehicle. It is strongly recommended that important structural members are adequately protected by concrete kerbs or similar method.

In areas with possibility of passenger vehicular impact, the precast components should be designed for an unfactored load of 27 kN, in any direction, acting at heights between 450 mm and 700 mm on an area not larger than 300 mm × 300 mm to produce maximum load effect. This load is not required to act concurrently with any handrail or guard rail system loads.

8.1.9 In all aspects of erection that affect structural design, it is essential that the designer should maintain a close liaison with the builder/contractor regarding the erection procedures to be followed.

8.1.10 Failures that have occurred during construction appear to be of two types. The first of these is the pack-of-cards type of collapse in which the absence of restraining elements, such as partitions, cladding or shear walls means that the structure is not stable during the construction period. The second is the situation in which one element falls during erection and lands on an element below. The connections of the lower element then give way under the loading, both static and dynamic, and a chain reaction of further collapse is set up.

8.1.10.1 A precaution against the first form of failure is that the overall stability of a building shall be considered in all its erection stages as well as in its completed state. All joints that may be required to resist moments and shears during the erection stage only, shall be designed with these in mind. Temporary works required to provide stability during construction shall be designed carefully.

8.1.10.2 To guard against the second form of failure, that is, the dropping of a unit during erection, particular attention shall be given to the details of all pre-formed units and to ensure that they are sufficiently robust to withstand the maximum stresses that can arise from site conditions. Precast concrete construction generally shall be capable of withstanding the impact forces that can arise from bad workmanship on site.

To ensure the stability of precast wall panel during erection, each panel should be supported by two inclined adjustable steel props with top end of the prop connected to the wall panel just above the mid height and lower end of the prop connected to floor slab through base plate. The inclination of the prop should be within 45° to 60° from horizontal.

8.1.11 The design shall take care of requirements owing to erection given at **11.11**.

8.1.12 In case of buildings whose floors are capable of providing rigid horizontal diaphragm action, the total shear in any horizontal plane shall be distributed to the various vertical elements of lateral forces resisting system, assuming the floors to be infinitely rigid in the horizontal plane.

In case of building whose floor diaphragms cannot be treated as infinitely rigid in their own plane, the lateral shear at each floor shall be distributed to the vertical elements resisting the lateral forces, considering the in-plane flexibility of the diaphragms.

NOTES

1 A floor diaphragm shall be considered to be flexible, if it deforms such that the maximum lateral displacement measured from the chord of the deformed shape at any point of the diaphragm is more than 1.5 times the average displacement of the entire diaphragm.

2 Reinforced concrete monolithic slab-beam floors or those consisting of prefabricated/precast elements with reinforced topping of thickness not less than 50 mm can be taken as a rigid diaphragm.

8.1.12.1 Floor systems play a key role in the lateral resistance of building structures by providing diaphragm action. Diaphragm action serves to:

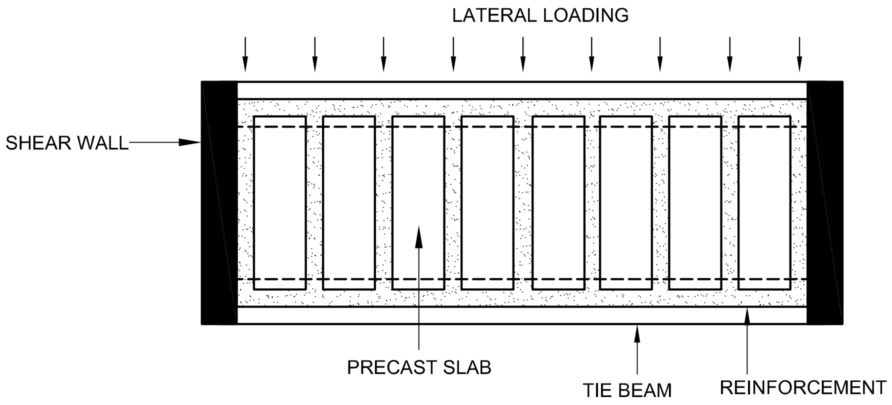
a) transfer lateral loads at each level to the lateral load-resisting elements (walls, frames); and
b) unite individual lateral load-resisting elements into a single lateral load-resisting system.

These actions are crucial in allowing the lateral (load-resisting) system to perform as intended. Diaphragm action occurs by virtue of the in-plane stiffness inherent in the floor system. Accordingly, significant in-plane forces may develop in the diaphragm during lateral loading. In this regard, the panelled nature of floor systems in precast concrete construction can present challenges in the seismic design of diaphragms. These design challenges may pertain to providing adequate strength, stiffness and in cases, ductility in the diaphragm and diaphragm connections.

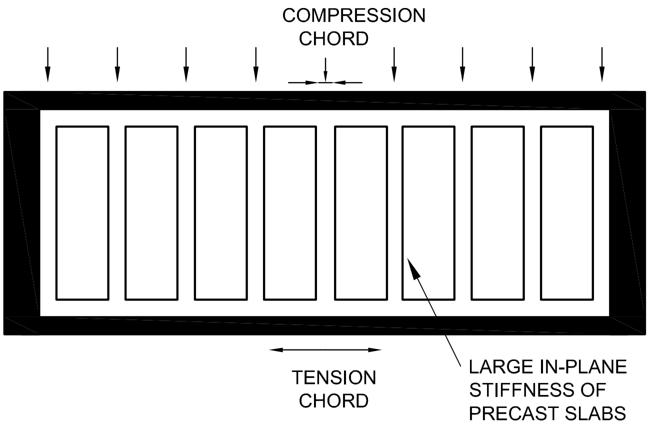
8.1.12.2 *Standard analysis methods for diaphragm design*

The magnitude of the inertia force at each floor level is estimated using a capacity design approach or a diaphragm design force distribution based on equivalent lateral loads. A key design step is to transform the diaphragm design forces into internal actions. For regular floor plans, a 'horizontal plate girder' analogy is typically used in design. In this approach, diaphragm design forces are typically applied at each level as a distributed in-plane load along the length of the diaphragm. The resulting girder internal forces are used to determine the amount of flexural reinforcement (chord steel), shear (web) reinforcement, and lateral system reaction load path reinforcement (collector steel). An irregular mass distribution in plan may require the design forces to take on a smeared load configuration as the mass distribution with respect to diaphragm depth has relevance in determining the proper web reinforcement.

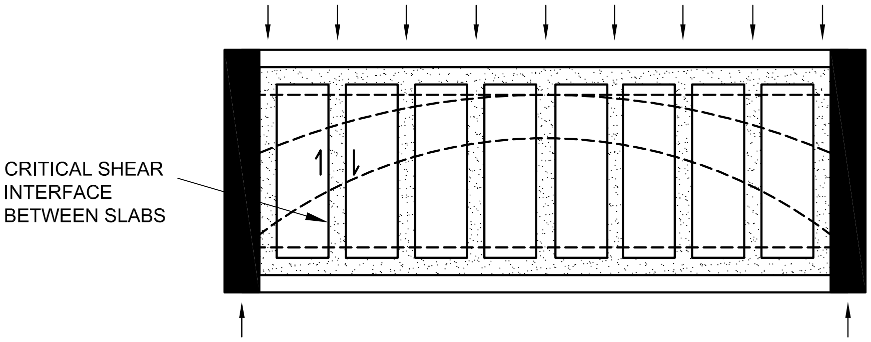
For more complex diaphragm configurations, a strut-and-tie method can be used. However, there is compelling evidence that the strut-and-tie method accurately predicts the behaviour of floor diaphragms, in general, and may become the preferred method of diaphragm analysis (*see* Fig. 3 and Fig. 4).



3A DIAGONAL TRUSS

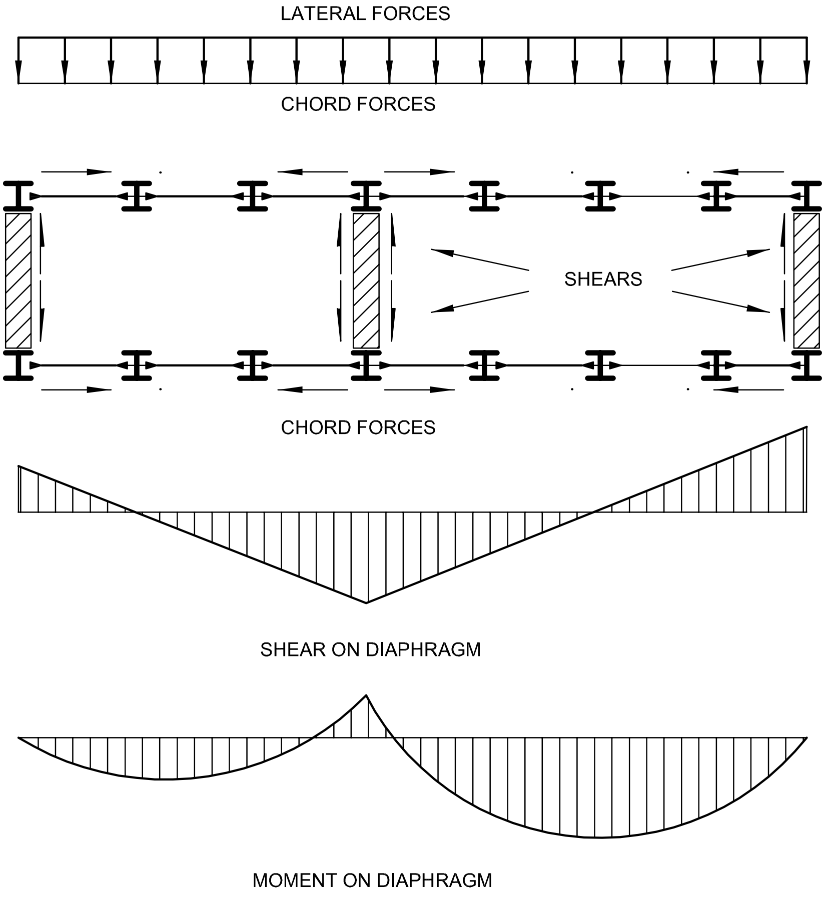


3B VIERENDEEL GIRDER



3C DEEP HORIZONTAL BEAM

Fig.3 Structural Models Used to Analyse Floor Diaphragms



NOTE – The floor deck is assumed to act as the web of the continuous beam and the beams at the floor periphery are assumed to act as the flanges of the continuous beam

FIG. 4 DESIGN FORCES ON A DIAPHRAGM

8.2 Design Requirements for Structural Integrity and Safety against Progressive Collapse

8.2.1 Prefabricated buildings shall be designed with proper structural integrity to avoid situations where damage to small areas of a structure or failure of single elements may lead to collapse of major parts of the structure.

The following precaution may generally provide adequate structural integrity,

a) All buildings should be capable of safely resisting the minimum horizontal load of 1.5 percent of characteristic dead load applied at each floor or roof level simultaneously (*see* Fig. 5).

b) All buildings shall be provided with effective horizontal ties,

   1) around the periphery;
   2) internally (in both directions); and
   3) to columns and walls.

c) All buildings of height more than 15 m shall be provided with vertical ties, not less than two ties for each precast panel, and shall be continuous over the height of the building.

In proportioning the ties, it may be assumed that no other forces are acting and the reinforcement is acting at its characteristic strength (that is, the material factor of safety is not applicable). Reinforcement provided for other purposes (for example, in compliance with **8.2.3.1**) may be regarded as forming a part of, or the whole of, these ties.

Normal procedure may be to design the structure for the usual loads and then carry out a check for the tie forces.

8.2.2 *Continuity and Anchorage of Ties*

Bars shall be lapped, welded or mechanically joined in accordance with IS 456.

8.2.3 *Design of Ties*

8.2.3.1 *Peripheral ties*

At each floor and roof level an effectively continuous tie should be provided within 1.2 m of the edge of the building or within the perimeter wall (*see* Fig. 6).

The tie should be capable to resist a tensile force of F_t equal to 60 kN or $(20 + 4N)$ kN, whichever is less, where N is the number of storeys (including basement).

8.2.3.2 *Internal ties*

These are to be provided at each floor and roof level in two directions approximately at right angles. Ties should be effectively continuous throughout their length and be anchored to the peripheral tie at both ends, unless continuing as horizontal ties to columns or walls (*see* Fig.7). The tensile strength, in kN/m width shall be the greater of :

$$\frac{(g_k + q_k)}{7.5} \cdot \frac{l_r F_t}{5} \text{ and } F_t$$

Where, $(g_k + q_k)$ is the sum of average characteristic dead and imposed floor loads, in kN/m^2, and l_r is the greater of the distance between the centre of columns, frames or walls supporting any two adjacent floor spans in the direction of the tie under consideration.

The bars providing these ties may be distributed evenly in the slabs (*see* Fig.8) or may be grouped at or in the beams, walls or other appropriate positions but at spacings generally not greater than 1.5 l_r.

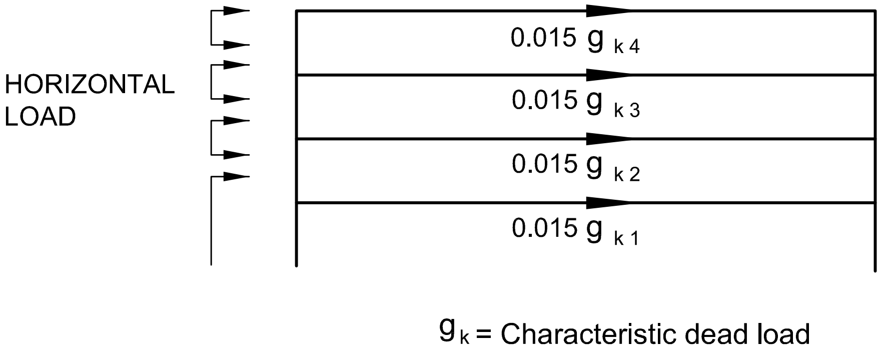
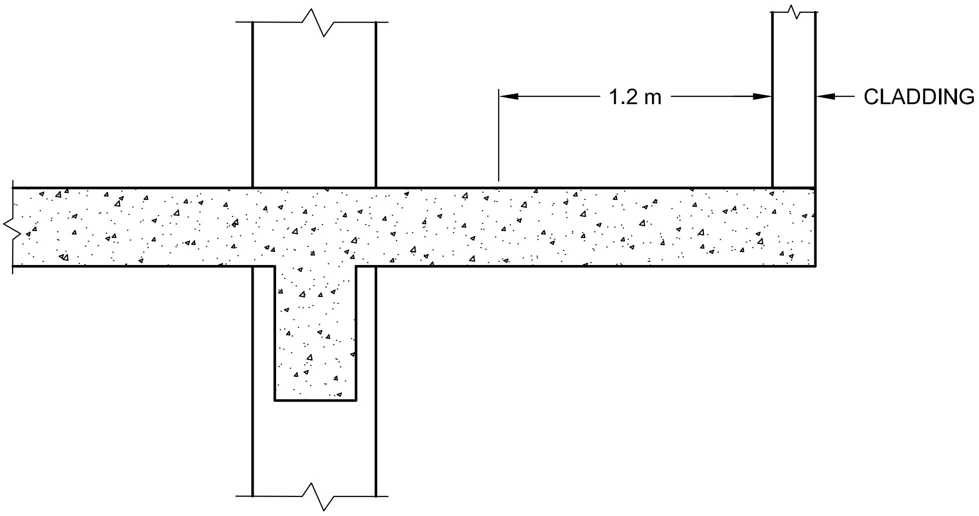
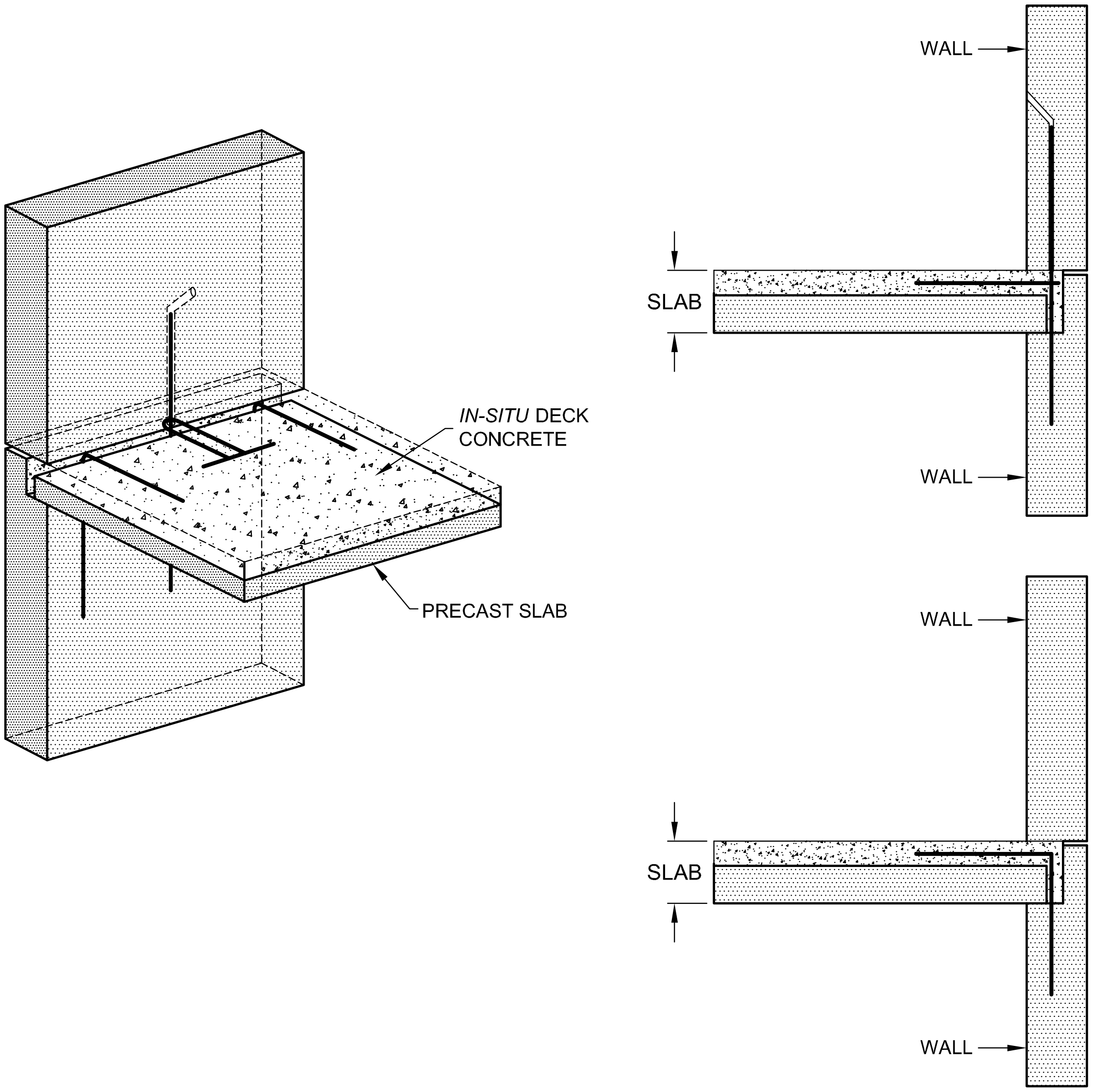


FIG. 5 HORIZONTAL LOADS

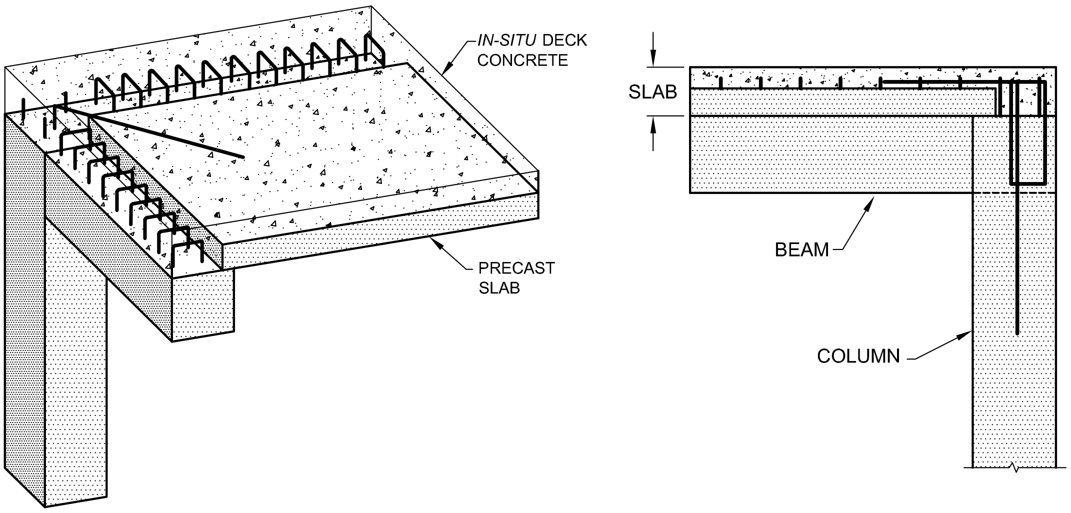


NOTE- If there are cantilever slabs, supporting external cladding, projecting in front of the columns and these are more than 1.2 m (*see* Fig. 6A), then the peripheral tie shall go in the slab as shown in Figs. 6B to 6F.

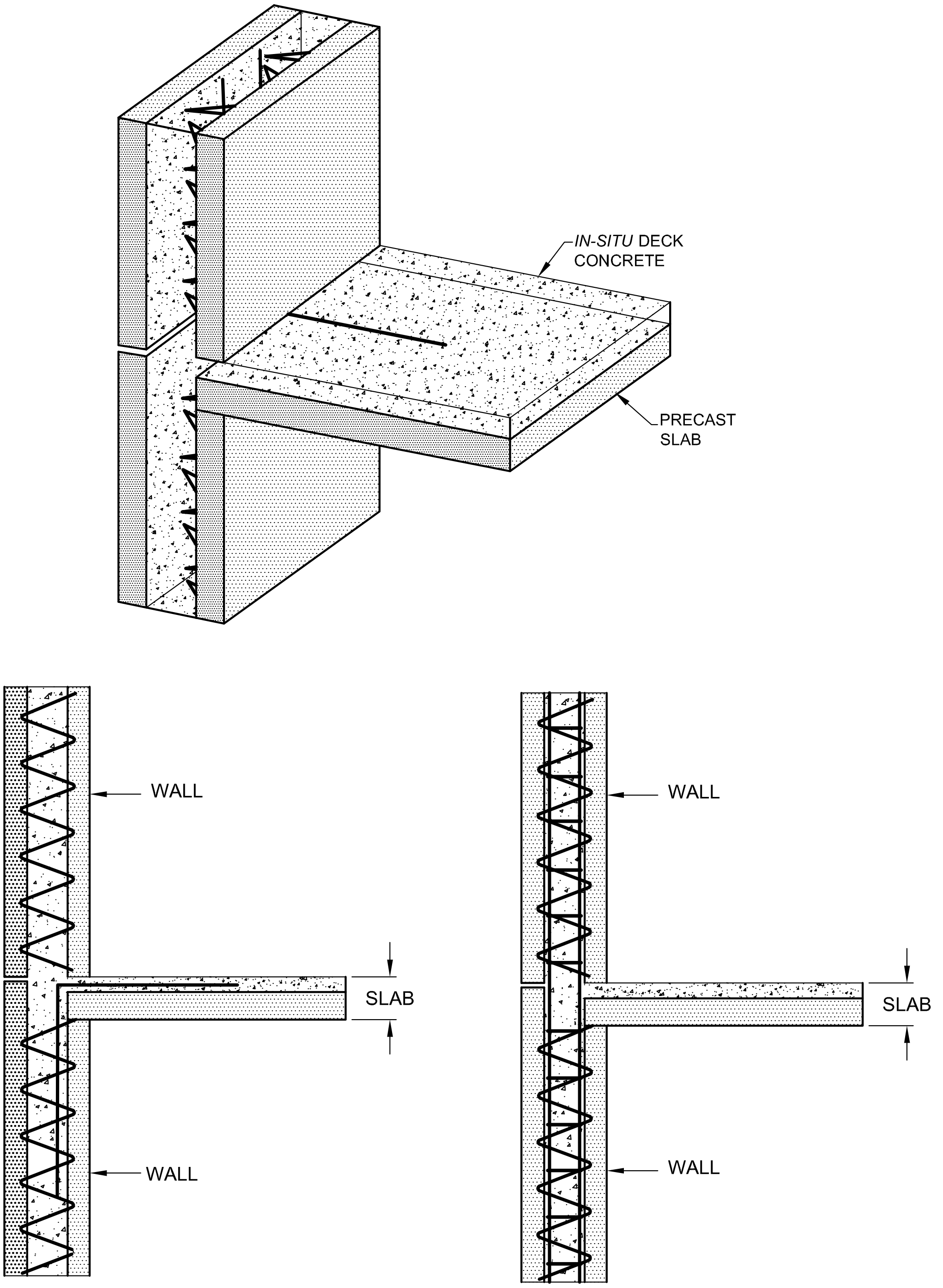
6A POSITION FOR PERIPHERAL TIE



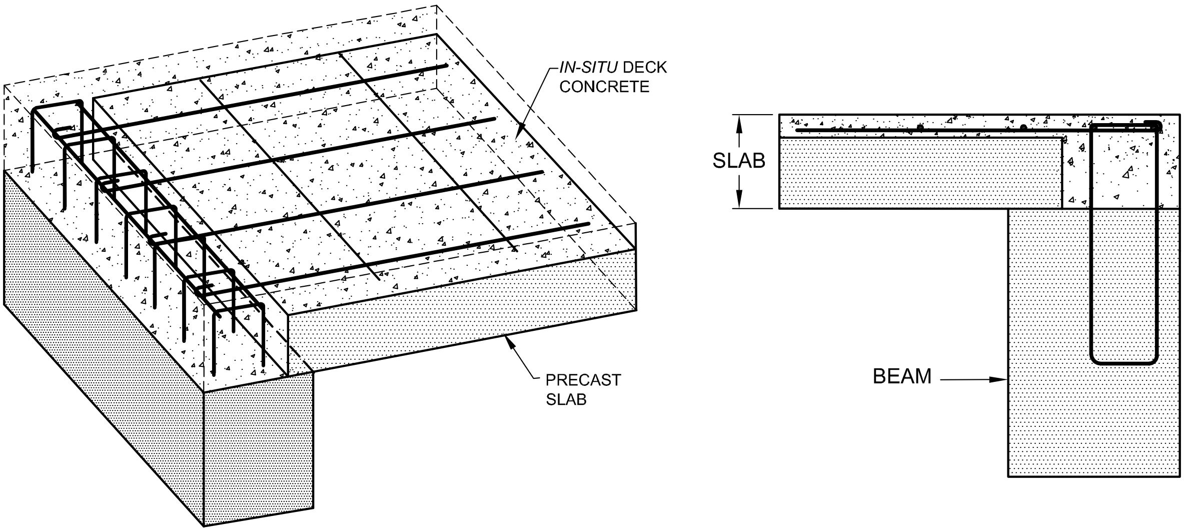
6B PRECAST WALL TO WALL CONNECTION WITH SHEATHING PIPE



6C PRECAST COLUMN, BEAM AND SLAB CONNECTION

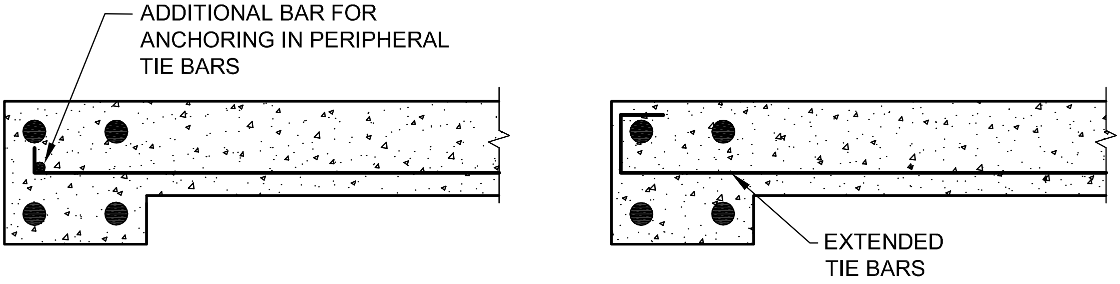


6D PRECAST DOUBLE WALL CONNECTION



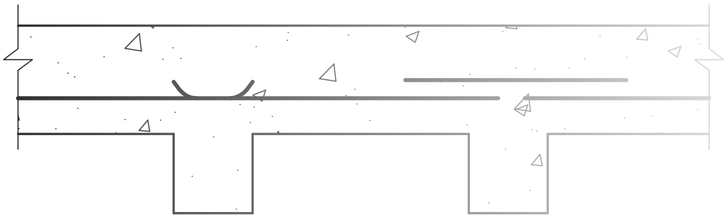
6E PRECAST BEAM SLAB CONNECTION

Fig. 6 Position for Peripheral Tie



NOTE - If the peripheral tie consists of bars in an edge beam, then the bottom bars in the slabs will not be at the same level as the peripheral tie bars. It is suggested that either an additional bar be used for anchoring in the peripheral tie or the internal tie bars be extended and anchored around the top bar in the beam.

Fig. 7 Anchoring of Ties in Slabs



NOTE – For continuity in continuous slabs, bars are distributed evenly in a floor slab by means of lapping some bottom steel at supports, either by extending existing bars or by the addition of splice bars.

Fig. 8 Continuity Requirement for Slab

8.2.3.3 *Horizontal ties to column and wall*

All external load-bearing members such as columns and walls should be anchored or tied horizontally into the structure at each floor and roof level. The design force for the tie is to be greater of:

a) $2F_t$ kN or $l_s \times F_t/2.5$ kN, whichever is less for a column or for each metre length, if there is a wall (l_s is the floor to ceiling height in metre).

b) 3 percent of the total ultimate vertical load in the column or wall at that level.

For corner columns, this tie force should be provided in each of two directions approximately at right angles.

8.2.3.4 *Vertical ties (for buildings of five or more storeys)*

Each column and each wall carrying vertical load should be tied continuously from the foundation to the roof level. The reinforcement provided is required only to resist a tensile force equal to the maximum design ultimate load (dead and imposed) received from any one storey.

In situation where provision of vertical ties cannot be done, the element should be considered to be removed and the surrounding members designed to bridge the gap.

8.2.4 *Key Elements*

For buildings of five or more storeys, the layout should be checked to identify key elements. A key element is, such that its failure would cause the collapse of more than a limited area close to it.

The limited area defined above may be taken equal to 70 m^2 or 15 percent of the area of the storey, whichever is lesser.

If key element exists, it is preferable to modify the layout so that the key element is avoided.

8.3 Bearing for Precast Units

8.3.1 *Jointed Precast Detailing*

The precast units shall have a bearing of at least of 100 mm on masonry supports and of 75 mm at least on steel or concrete. Steel angle shelf bearings shall have a 100 mm horizontal leg to allow for a 50 mm bearing exclusive of fixing clearance. When deciding to what extent, if any, the bearing width may be reduced in special circumstances , factors such as, loading, span, height of wall and provision of continuity shall be taken into consideration.

8.3.2 *Emulative Precast Detailing*

In emulative precast detailing, the structure under service conditions behaves similar to a cast *in-situ* structure and inherits the redundancy due to continuity. Typically, the components are tied together with appropriate steel ties and connected using a cast *in-situ* 'stitch' concrete pour for near monolithic continuity. The bearing for the building components thus becomes a critical concern only during the erection stages. The precast members, in emulative detailing system, shall have a bearing of at least 40 mm on concrete support components. In cases, where the supports are in steel or masonry system where emulative detailing is not followed in local limited areas, bearing of at least 75 mm for steel support and 100 mm for masonry support should be provided. Otherwise, for both systems, bearing of at least 40 mm should be provided at the structural engineer's discretion. In special circumstances, where additional temporary supports/ shoring is provided during erection, bearing of at least 25 mm should be acceptable at the structural engineer's discretion. Such temporary supports shall be kept in place until the 'stitch' concrete pour gains at least 70 percent of the final design strength

9 JOINTS

9.1 The design of joints shall be made in the light of their assessment with respect to the following considerations:

a) *Feasibility* — The feasibility of a joint shall be determined by its load carrying capacity in the particular situation in which the joint is to function.

b) *Practicability* — Practicability of joint shall be determined by the amount and type of material required in construction; cost of material, fabrication and erection and the time for fabrication and erection.

c) *Serviceability* — Serviceability shall be determined by the joints/expected behaviour to repeated or possible overloading and exposure to climatic or chemical conditions.

d) *Fire rating* — The fire rating for joints of precast components shall be higher or at least equal to connecting members.

NOTE — Fire resistance testing under sustained loading may also be carried out on a prototype, as mutually agreed between the parties concerned.

e) *Appearance* — The appearance of precast component's joints shall merge with architectural aesthetic appearance and shall not be physically prominent compared to other parts of structural components.

f) *Water tightness of joints* — In buildings, the external joints between precast elements should be water tight to ensure the durability requirements. If the joints are not water tight, it may lead to corrosion of reinforcing steel due to exposure to moisture thereby impacting the structural integrity. Also, water can enter inside the building and impact the functionality in service life of the building. In case of precast reinforced concrete wall buildings, joints of external walls, in addition to their structural efficiency, shall be watertight. For non-load bearing/facade walls, the connections shall allow free movement of the walls due to temperature changes. This can be achieved by suitably shaping the joint or by sealing compounds. In load bearing external/internal walls, the horizontal and vertical joints shall be filled with non-shrink, non-metallic, flowable high strength cementitious grout followed by backer rod (bond breaker such as polyethylene film also can be used in place of backer rod) with sealant at the external side. Where the joints are wider, the grout mix can be modified by adding 10 mm down aggregates as per the grout manufacturer's guidelines as approved by the Engineer-in-Charge. The sealing compound shall be approved by the Engineer-in-Charge and shall have a long life to avoid frequent repair of the joints (*see* Note). It should be noted that the sealant is provided as an additional line of defense against water entry. In cases of moderate water exposure, the joints could be detailed with cement grout only with appropriate additional water proofing treatment instead of sealant (*see* **10.4**).

NOTE — The sealant should be considered as a replaceable element of the structure with a desired life of 10-15 years.

g) The joint shall be filled with material considering its permanence/lasting quality.

9.2 The following are the requirements of a structural joint:

a) It shall be capable of being designed to transfer the imposed load and moments with a known margin of safety;

b) It shall occur at logical locations in the structure and at points which may be most readily analyzed and easily reinforced;

c) It shall accept the loads without marked displacement or rotation and avoid high local stresses;

d) It shall accommodate tolerances in elements;

e) It shall require little temporary support, permit adjustment and demand only a few distinct operations to make;

f) It shall permit effective inspection and rectification;

g) It shall be reliable in service with other parts of the building; and

h) It shall enable the structure to absorb sufficient energy during earthquakes so as to avoid sudden failure of the structure (*see* Note). The joint should be ductile.

NOTE — If required, tests may be carried out on prototypes to assess against the above requirement.

j) Vertical joints may be designed as structural joints to emulate the conventional reinforced concrete joint with appropriate reinforcement across the joint or as non-structural joints with nominal reinforcement required for alignment, thermal and shrinkage loads. The structural analysis model should reflect the joint restraints accordingly.

9.2.1 Precast structures may have continuous or hinged connections subject to providing sufficient rigidity to withstand horizontal loading. When only compressive forces are to be taken, hinged joints may be adopted. In case of prefabricated concrete elements, load is transmitted *via* the concrete. When both compressive force and bending moment are to be taken, rigid or welded joints may be adopted; the shearing force is usually small in the column and can be taken up by the friction resistance of the joint. Here load transmission is accomplished by steel inserted parts together with concrete. In precast structures, it is critical to minimize relative movements of precast components under loads. Hence, connection details that rely solely on the frictional resistance under gravity loads are not permitted. The connections shall be designed using either the pure shear capacity of the connection element or based on the shear friction theory that takes the advantage of the frictional resistance of concrete components under gravity loads.

9.2.2 When considering thermal shrinkage and heat effects, provision of freedom of movement or introduction of restraint may be considered.

9.3 Following connections and jointing techniques/materials may be employed:

a) Welding of cleats or projecting steel;

b) Overlapping reinforcement, loops and linking steel grouted by concrete;

c) Reinforced concrete ties all around a slab;

d) Pre-stressing;

e) Epoxy grouting;

f) Cement/lime grout with non-shrink additive;

g) Polymer slurry grouting at dowel cast bolts and nuts connection;

h) Rebar fastener, chemical fastener and expansion fastener;

j) Reinforcement coupler;
k) Combination of the above; and
m) Any other method proven by test.

9.4 Precast Joint Connections

Typical figures of some of the common precast joint connections are given in Annex C.

10 TESTS FOR COMPONENTS/STRUCTURES

10.1 Sampling Procedure

10.1.1 *Lot*

All the precast units of the same size, manufactured from the same material under similar conditions of production shall be grouped together to constitute a lot.

The number of units to be selected from each lot for dimensional requirements shall depend upon the size of the lot and shall be in accordance with col 3 and col 4 of Table 1.

Table 1 Sample Size and Rejection Number

(*Clauses* 10.1.1 *and* 10.1.2)

Sl No.	Lot Size	First Sample Size	Second Sample Size	First Rejection Number	Second Rejection Number
(1)	(2)	(3)	(4)	(5)	(6)
i)	Up to 100	5	5	2	2
ii)	101 to 300	8	8	2	2
iii)	301 to 500	13	13	2	2
iv)	500 and above	20	20	3	4

The units shall be selected from the lot at random. In order to ensure the randomness of selection, reference may be made to IS 4905.

10.1.2 *Number of Tests and Criteria for Conformity*

All the units selected at random in accordance with col 3 and col 4 of Table 1 shall be subjected to the dimensional requirements. A unit failing to satisfy any of the dimensional requirements shall be termed as defective. The lot shall be considered as conforming to the dimensional requirements if no defective is found in the sample, and shall be rejected if the number of defectives is greater than or equal to the first rejection number. If the number of defectives is less than the first rejection number, the second sample of the same size as taken in the first stage shall be selected from the lot at random and subjected to the dimensional requirements. The number of defectives in the first sample and the second sample shall be combined and if the combined number of defectives is less than the second rejection number, the lot shall be considered as conforming to the dimensional requirements; otherwise not.

The lot which has been found as satisfactory with respect to the dimensional requirements shall then be tested for load test. For this purpose, one unit shall be selected for every 300 units or part thereof. The lot shall be considered as conforming to the strength requirement, if all the units meet the requirement; otherwise not.

10.2 Testing on Individual Components

The component should be loaded for 24 h at its full span with a total load (including its own self weight) of 1.25 times F_{lt}, where F_{lt} is the sum of the dead and imposed loads used in design. At the end of this time it should not show any sign of weakness, faulty construction or excessive deflection. Its recovery 24 h after the removal of the test load, should not be less than 75 percent of the maximum deflection recorded during the test. If prestressed, it should not show any visible cracks up to working load and should have a recovery of not less than 85 percent in 1 h.

10.3 Load Testing of Structure or Part of Structure

Loading test on a completed structure should be made, if required by the specification or if there is a reasonable doubt as to the adequacy of the strength of the structure.

10.3.1 In such tests, the structure should be subjected to full dead load of the structure plus an imposed load equal to 1.25 times the specified imposed load used in design for a period of 24 h and then the imposed load shall be removed. During the tests, vertical struts equal in strength to take the whole load should be placed in position leaving a gap under the member.

NOTE — Dead load includes self-weight of the structural members plus weight of finishes and walls or partitions, if any, as considered in the design.

10.3.1.1 If within 24 h of the removal of the load, a reinforced concrete structure does not show a recovery of at least 75 percent of the maximum deflection shown during the 24 h under load, test loading should be repeated after a lapse of 72 h. If the recovery is less than 80 percent in second test, the structure shall be deemed to be unacceptable.

10.3.1.2 If within 24 h of the removal of the load, a prestressed concrete structure does not show a recovery of at least 85 percent of the maximum deflection shown during the 24 h under load, the test loading should be repeated. The structure should be considered to have failed, if the recovery after the second test is not at least

85 percent of the maximum deflection shown during the second test.

10.3.1.3 If the maximum deflection in mm, shown during 24 h under load is less than 40 l^2/D, where l is the effective span in m; and D, the overall depth of the section in mm, it is not necessary for the recovery to be measured and the recovery provisions of **10.3.1.1** and **10.3.1.2** shall not apply.

10.4 Testing of External Precast Wall/Facade Panels for Water Tightness

Any of the testing procedures given in **10.4.1** and **10.4.2** may be followed for testing of external wall/facade panel joints for water tightness.

10.4.1 *Testing Procedure 1*

10.4.1.1 *General*

If it is deemed necessary to demonstrate that the precast facade joints are adequate to resist water penetration, a water penetration test on a full scale panel including joint mock-ups could be undertaken.

10.4.1.2 *Test procedures*

Mock-up panels to be tested for water tightness should be subjected to both static and cyclic pressure in accordance with standard accepted procedures. Available international testing procedures are to be modified for local conditions as follows:

a) Differential test pressure shall be 20 percent of the maximum inward design wind load but not less than 0.77 kPa; and
b) The test shall be performed with water flow rate of 3.4 litres/min/m² for 15 min.

10.4.1.3 *Sampling for water penetration test*

Full scale water tightness testing on precast facade panels and joints should be carried out at the rate of 0.5 percent for each type of joint and combination of panels or one for each type of joint and precast unit, whichever is the greater.

10.4.1.4 *Failure criterion*

The facade units or joints are deemed to have failed, if signs of water seepage through the joints or through the facade unit, including signs of damp patches, are observed during the test or within the subsequent 2 h after the test.

10.4.1.5 *Remedial action on failure*

Upon failure of a water penetration test on a precast facade system the cause of failure should be identified and the system revised and re-tested until a satisfactory test result is achieved. Modifications shall be realistic in terms of job conditions and shall maintain standards of quality and durability.

10.4.2 *Testing Procedure 2*

10.4.2.1 For external walls, a continuous jet of water shall be sprayed on the joint corresponding to 600 litres/h from a water hose having nozzle velocity of 2 m/s and a cone scatter of approximately 60° held at a distance of 1.2 m from the wall surface under test. The duration of the test shall not be less than 2 h. The hose shall be placed centred on the horizontal or vertical joint width.

For external walls, the following tests shall be conducted for each building block:

Building Height	*Frequency of Tests*
Up to 10 storeys	5 tests each for vertical joints and horizontal joints
Up to 20 storeys	10 tests each for vertical joints and horizontal joints
Up to 30 storeys	15 tests each for vertical joints and horizontal joints
Up to 40 storeys	20 tests each for vertical joints and horizontal joints
Up to 50 storeys	25 tests each for vertical joints and horizontal joints

Twenty percent of these tests shall be carried out at the intersection of vertical and horizontal joint.

These tests shall be carried out at any location as instructed by the Engineer-In-Charge.

10.4.2.2 *Acceptance criterion*

Water shall not seep into any part of the building during the test.

10.4.2.3 *Remedial action on failure*

For each test which fails, the tested joint should be repaired as per the approved repair procedure as directed by the Engineer-in-Charge and the joint shall be retested for performance as per **10.4.2.2**. Two additional joints should be tested for each failed joint unless directed otherwise by the Engineer-in-Charge at the cost and expense of contractor, including the cost of repair work.

11 MANUFACTURE, STORAGE, TRANSPORT AND ERECTION OF PRECAST ELEMENTS

11.1 Manufacture of Precast Concrete Elements

11.1.1 A judicious location of precasting yard with concreting, initial curing (required for demoulding), storage facilities, suitable transportation and erection equipment and availability of raw materials are the crucial factors which should be carefully planned and provided for effective and economic use of precast concrete components in construction.

11.1.2 *Manufacture*

The manufacture of the components can be done in a factory for the commercial production established at the focal point based on the market potential or in a site pre-casting yard set up at or near the site of work.

11.1.2.1 *Factory prefabrication*

Factory prefabrication is resorted to in a factory for the commercial production for the manufacture of standardized components on a long term basis. It is a capital intensive production where work is done throughout the year preferably under a closed shed to avoid effects of seasonal variations. High level of mechanization can always be introduced in this system where the work can be organized in a factory-like manner with the help of a constant team of workmen.

11.1.2.2 *Site prefabrication*

In this scheme, prefabricated components are produced at site or as near the site of work as possible.

This system is normally adopted for a specific job order of large scale that will continue over a long period. This option provides definite economy with respect to cost of transportation thereby improving productivity. Even though temporary, the factory established should be comparable to high capacity permanent factory with equivalent state-of-the-art degree of mechanization and quality control. Under this category there are two types, that is, semi-mechanized and fully-mechanized.

a) *Semi-mechanized* — The work is normally carried out in open space with locally available labour force or skilled labour force depending on project complexity. The equipment/machinery used may be minor in nature and moulds are of mobile or stationary in nature.
b) *Fully-mechanized* — The work is carried out under a shed with skilled labour. The equipment used are similar to those of factory production. This type of precast yard will be set up for the production of precast components of high quality with a high rate of production.

11.1.3 The various processes involved in the manufacture of precast elements may be classified as follows.

11.1.3.1 *Main process*

a) Providing and assembling the moulds, placing reinforcement cage in position for reinforced concrete work, and stressing the wires in the case of prestressed elements;
b) Putting concealed service conduits/pipes;
c) Fixing of inserts and tubes, where necessary (for handling);
d) Pouring the concrete (designed properly under strict quality control) into the moulds;
e) Vibrating the concrete and finishing;
f) Curing (steam curing, if necessary); and
g) Demoulding the forms and stacking the precast products.

11.1.3.2 *Auxiliary process*

Process, such as the following, necessary for the successful completion of the processes covered by the main process:

a) Mixing and manufacture of fresh concrete (done in a mixing station orby a batching plant);
b) Prefabrication of reinforcement cage (done in a steel yard or workshop);
c) Manufacture of inserts and other finishing items to be incorporated inthe main precast products;
d) Finishing the precast products; and
e) Testing of products.

11.1.3.3 *Subsidiary process*

All other work, such as the following, involved in keeping the main production work to a cyclic working:

a) Storage of materials;
b) Transport of cement and aggregates;
c) Transport of green concrete and reinforcement cages;
d) Transport and stacking the precast elements;
e) Repairs and maintenance of tools, shackles and machines;
f) Repairs and maintenance of moulds;
g) Maintenance of curing yards; and
h) Generation of steam, etc.

11.1.4 For the manufacture of precast elements all the above processes shall be planned in a systematic way to achieve the following:

a) A cyclic technological method of working to bring in speed and economy in manufacture;
b) Mechanization of the process to increase productivity and to improve quality;
c) The optimum production satisfying the quality control requirements and to keep up the expected speed of construction aimed;
d) Better working conditions for the people on the job; and
e) Minimizing the effect of weather on the manufacturing schedule.

11.1.5 The various stages of pre-casting can be classified as given in Table 2 on the basis of the equipment required for the various stages. This permits mechanization and rationalization of work in the various stages. In the pre-casting, stages 6 and 7 given in Table 2 form the main process in the manufacture of precast concrete elements. For these pre-casting stages, there are many technological processes to suit the concrete product under consideration which have been proved rational, economical and time saving. The technological line or process is the theoretical solution for the method of planning the work involved by using machine complexes. Figure 9 illustrates diagrammatically the various stages involved in a plant process.

11.1.6 The various accepted methods of manufacture of precast units can be broadly classified into two methods:

a) The 'stand method' where the moulds remain stationary at places, when the various processes involved are carried out in a cyclic order at the same place; and

b) The 'flow method' where the precast unit under consideration is in movement according to the various processes involved in the work which are carried out in an assembly-line method.

Table 2 Stages of Precasting of Concrete Products

(*Clause* 11.1.5)

Sl No.	Precasting Stage No.	Name of Process	Operations Involved
(1)	(2)	(3)	(4)
i)	1	Procurement and storage of construction materials	Unloading and transport of cement, coarse and fine aggregates and steel, and storing them in bins, silos or storage sheds
ii)	2	Testing of materials	Testing of all materials including steel
iii)	3	Design of concrete mix	Testing of raw materials, plotting of grading curves and trial of mixes in laboratory
iv)	4	Making of reinforcement cages	Unloading of reinforcement bars from wagons or lorries and stacking them in the steel yard, cutting, bending, tying or welding the reinforcements and making in the form of a cage, which can be directly introduced into the mould
v)	5	Applying form release agent and laying of moulds in position	Moulds are cleaned, applied with form release agent, and assembled and placed at the right place
vi)	6	Placing of reinforcement cages, inserts and fixtures	The reinforcement cages are placed in the moulds with spacers, etc, as per data sheet prepared for the particular prefabricate
vii)	7	Preparation of green concrete	Taking out aggregates and cement from bins, silos, etc, batching and mixing
viii)	8	Transport of green concrete	Transport of green concrete from the mixer to the moulds. In the case of precast method involving direct transfer of concrete from mixer to the mould or a concrete hopper attached to the mould this prefabrication stage is not necessary
ix)	9	Pouring and consolidation of concrete	Concrete is poured and vibrated to a good finish
x)	10	Curing of concrete and demoulding	Either a natural curing with water or an accelerated curing using steam and other techniques. In the case of steam curing using trenches or autoclaves, this stage involves transport of moulds with the green concrete into the trench or autoclave and taking them out after the curing and demoulding elements. Cutting of protruding wires also falls in this stage. In certain cases the moulds have to be partly removed and inserts have to be removed after initial set. Final demoulding is done after concrete has gained designed strength, enough to resist handling stress, and the components are then allowed to be cured further. All these fall in this operation
xi)	11	Stacking of precast elements	Lifting of precast elements from the mould and transporting to the stacking yard for further transport by trailer or rail is part of this stage
xii)	12	Testing of finished components	Tests are carried out on the components individually and in combination to ensure the adequacy of their strength
xiii)	13	Miscellaneous	a) Generation of steam involving storing of coal or oil necessary for generation of steam and providing insulated steam pipe connection up to the various technological lines b) Repair of machines used in the production

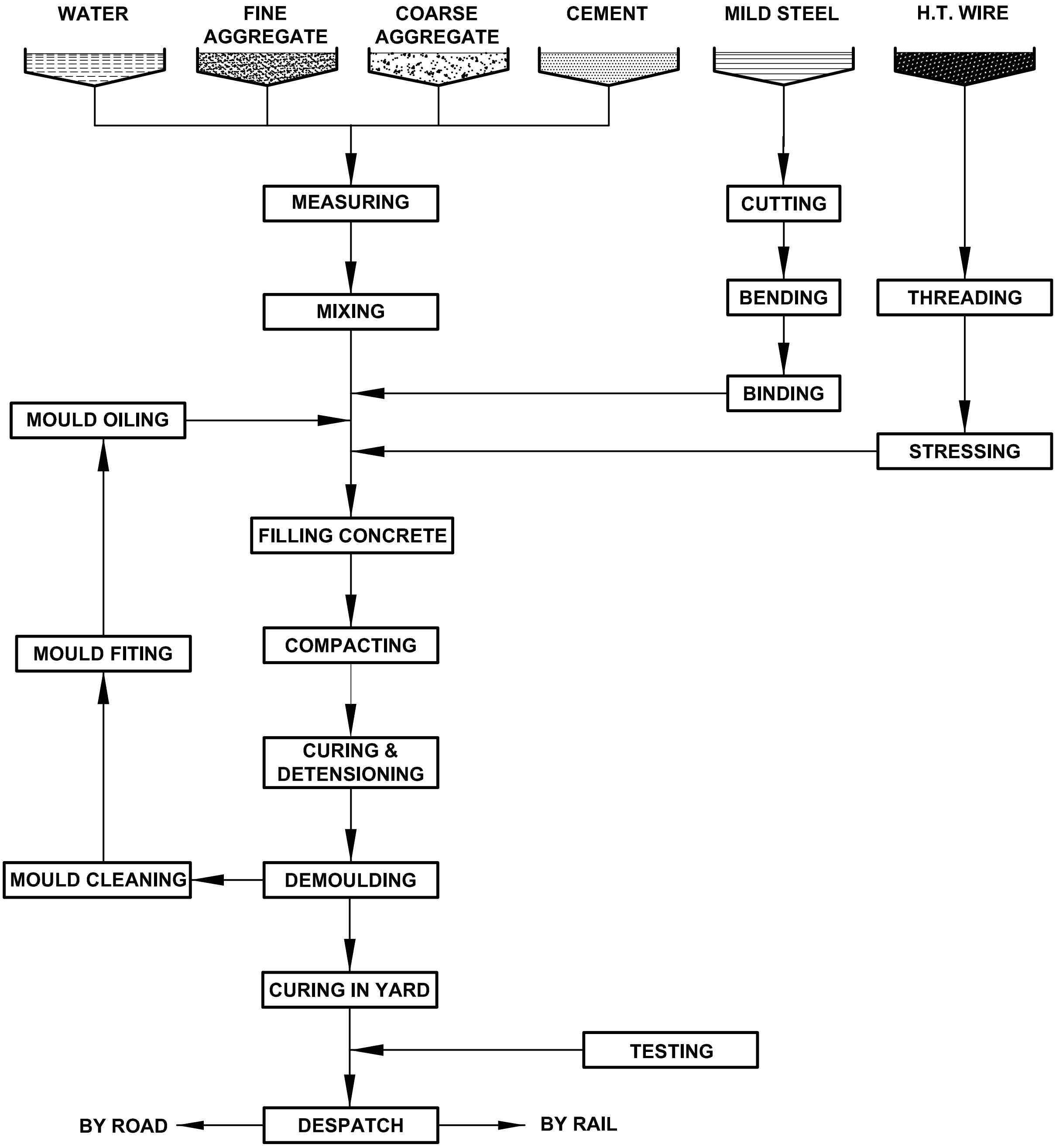


FIG. 9 PLANT PROCESS

The various accepted pre-casting methods are listed in Table 3 with details regarding the elements that can be manufactured by these methods.

11.2 Preparation and Storage of Materials

Storage of materials is of considerable importance in the pre-casting industry as a mistake in planning in this aspect can greatly influence the economics of production. From experience in construction, it is clear that there will be very high percentage of loss of materials as well as poor quality due to improper storage and transport. So, in a precast factory where everything is produced with special emphasis on quality, proper storage and preservation of building materials, especially cement, coarse and fine aggregates is of prime importance. Storage of materials shall be done in accordance with IS 4082. Also, precast elements be subjected to ‘first-in first-out’ to minimize and/or avoid issues relating to shrinkage, creep, etc.

11.3 Moulds

11.3.1 Moulds for the manufacture of precast elements may be of steel, timber, concrete and plastic or a combination thereof. For the design of moulds for the various elements, special importance should be given to easy demoulding and assembly of the various parts. At the same time rigidity, strength and water-tightness of the mould, taking into consideration forces due

Table 3 Precasting Methods

(*Clauses* 11.1.6 *and* 11.9.1)

Sl No. (1)	Precasting Method (2)	Where Used (3)	Recommended Dimensions and Weights (4)	Advantages and Remarks (5)
i)	*Individual mould method* — Precasting method using mould which may be easily assembled out of bottom and sides, transportable, if necessary. This may be either in timber or in steel using needle or mould vibrators and capable of taking pre-stressing forces	a) Ribbed slabs, beams, girders, window panels, box type units and special elements b) Prestressed railway sleepers, parts of pre-stressed girders, etc.	No limit in size and weight. Depends on the equipment used for demoulding, transporting and placing	a) Strengthening of the cross-section possible b) Openings are possible in two planes
ii)	*Battery form method* — The shuttering panels may be adjusted into the form of a battery at the required distances equal to the thickness of the concrete member	Interior wall panels, shell elements, reinforced concrete battens, rafters, purlins, and roof and floor slabs	a) Length : 18 m b) Breadth : 3 m c) Mass : 5 t	Specially suitable for mass production of wall panels where shuttering cost is reduced to a large extent and autoclave or trench steam curing may be adopted by taking the steam pipes through the shuttering panels
iii)	*Stack method*	Floor and roof slab panels	a) Length : Any desired length b) Breadth : 1 to 4 m c) Mass : 5 t	For casting identical reinforced or pre-stressed panels one over the other with separating media interposed in between
iv)	*Tilting mould method* — This method is capable of being skipped vertically using hydraulic jacks	Exterior wall panels where special finishes are required on one face or for sandwich panel	a) Length : 6 m b) Breadth : 4 m c) Mass : 5 t	Suitable for manufacturing the external wall panels
v)	*Long line prestressing bed method*	Double tees, ribbed slabs, purlins, piles and beams	a) Length : Any Desired length b) Breadth : 2 m c) Height : 2 m d) Mass : Up to 10 t	Ideally suited for pretension members
vi)	*Extrusion method* —Long concrete mould with constant cross-section where concreting and vibration are done automatically just as in hollow cored slab casting	Roof slabs, foam concrete wall panels and beams cross-section	a) Length : Any Desired length b) Breadth : Less than 2 m c) Height : Less than 3 m	May be used with advantage in the case of un-reinforced blocks, foam concrete panels

to pouring of green concrete and vibrating, are also important. The deflection of all the supporting member of the mould should not be more than $\frac{L}{350}$ or 3 mm, whichever is less, where L is span of the member in mm.

11.3.2 *Tolerances*

The moulds have to be designed in such a way as to take into consideration the tolerances given in **6.2**.

11.3.3 *Slopes of the Mould Walls*

For easy demoulding of the elements from the mould with fixed sides, where precast elements have to be lifted out of mould, the side slopes should preferably be 1 in 6 but never less than 1 in 12. Otherwise, there is a possibility of the elements getting stuck up with the mould at the time of demoulding.

11.4 Accelerated Hardening

In most of the precasting factories, it is economical to use faster curing methods or artificial curing methods which, in turn will allow the elements to be demoulded much earlier permitting early re-use of the forms. Any of the following methods may be adopted:

a) *By heating the aggregates and water before mixing the concrete* — By heating of the aggregates as well as water to about 70 °C to 80 °C before making the concrete mix and placing the same in the moulds, sufficiently high earlier strengths are developed to allow the elements to be stripped and transported.

b) *Steam curing* — Steam curing may be done under high pressure and high temperature in an autoclave. This technique is more suited to smaller elements. Alternatively, this could be done using low pressure steam having temperature around 80 °C. This type of curing shall be done as specified in **11.5.2**. For light weight concrete products when steam cured under high pressure, the drying shrinkage is reduced considerably. Due to this reason, high pressure steam curing in autoclave is specified for light weight low densities ranging from 300 to 1 000 kg/m^3. For normal (heavy) concretes as well as light weight concretes of higher densities, low pressure steam curing may be desirable as it does not involve using high pressures and temperatures requiring high investment in an autoclave (*see also* **11.5.2**).

c) *Steam injection during mixing of concrete* — In this method, low pressure saturated steam is injected into the mixer while the aggregates are being mixed. This enables the heating up of concrete to approximately 60 °C. Such a concrete after being placed in the moulds attains high early strength.

d) *Heated air method* — In this method, the concrete elements are kept in contact with hot air with a relative humidity not less than 80 percent. This method is specially useful for light weight concrete products using porous coarse aggregates.

e) *Hot water method* — In this method, the concrete elements are kept in a bath of hot water around 50 °C to 80 °C. The general principles of this type of curing are not much different from steam curing.

f) *Electrical method* — The passage of current through the concrete panels generates heat through its electro-resistivity and accelerates curing. In this method, the concrete is heated up by an alternating current ranging from 50 V for a plastic concrete and gradually increasing to 230 V for the set concrete. This method is normally used for massive concrete products.

11.4.1 After the accelerated hardening of the above products by any of the above accepted methods, the elements shall be cured further by normal curing methods to attain full final strength.

11.4.2 Accelerated hardening may also be achieved by the following techniques:

a) *Construction chemicals* — Suitable construction chemicals may be used.

b) *Consolidation by spinning* — Such a method is generally used in the centrifugal moulding of pipes and such units. The spinning motion removes excess water, effects consolidation and permits earlier demoulding.

c) *Pressed concrete* — This method is suitable for fabrication of small or large products at high speed of production. A 100 to 200 t press compresses the wet concrete in rigid moulds and expels water. Early handling and a dense wear resistant concrete is obtained.

d) *Vacuum treatment* — This method removes the surplus air and water from the newly placed concrete as in slabs and similar elements. A suction upto about 70 percent of an atmosphere is applied for 20 to 30 min/cm thickness of the units.

e) *Consolidation by shock* — This method is suitable for small concrete units dropped repeatedly from a height in strong moulds. The number of shocks required to remove excess water and air may vary from 6 to 20 and the height of lift may be up to as much as half the depth of the mould.

11.4.3 After the accelerated curing of the above products by any of the above accepted methods, the elements shall be cured further by normal curing methods to attain full final strength.

11.5 Curing

11.5.1 The curing of the prefabricated elements can be effected by the normal methods of curing by sprinkling water and keeping the elements moist. This can also be done in the case of smaller elements by immersing them in a specially made water tanks.

11.5.2 *Steam Curing*

11.5.2.1 The steam curing of concrete products shall take place under tarpaulin in tents, under hoods, under chambers, in tunnels or in special autoclaves. The steam shall have a uniform quality throughout the length of the member. The precast elements shall be so stacked with sufficient clearance between each other and the bounding enclosure, so as to allow proper circulation of steam.

Before the concrete products are subjected to any accelerated method of curing, the cement to be used shall be tested in accordance with relevant Indian Standards, especially for soundness, setting time and suitability for steam curing.

In the case of elements manufactured by accelerated curing methods, concrete admixtures to reduce the water content may be allowed to be used. The normal aeration agents used to increase the workability of concrete should not be allowed to be used. Use of calcium chloride based admixtures should not be used for reinforced concrete elements so as to meet the chloride limits prescribed in IS 456.

11.5.2.2 The inside face of the steam curing chamber, tunnel or hood shall have a damp-proof layer to maintain the humidity of steam. Moreover, proper slope shall be given to the floor and the roof to allow the condensed water to be easily drained away. At first, when steam is let into the curing chambers, the air inside shall be allowed to go out through openings provided in the hoods or side walls which shall be closed soon after moist steam is seen jetting out.

11.5.2.3 It is preferable to let in steam from the top of the chamber through perforated pipelines to allow uniform entry of steam throughout the chamber.

11.5.2.4 The fresh concrete in the moulds should be allowed to get the initial set before allowing the concrete to come into contact with steam. The regular heating up of fresh concrete product from about 20 °C to 35 °C should start only after a waiting period ranging from 2 h to 5 h depending on the setting time of cement used. It may be further noted that steam can be let in earlier than this waiting period provided the temperature of the concrete product does not rise beyond 35 °C within this waiting period.

11.5.2.5 The second stage in steam curing process is to heat up the concrete elements, moulds and the surroundings in the chamber:

a) In the low pressure steam curing, the airspace around the member is heated upto a temperature of 75 °C to 80 °C at a gradual rate, usually not faster than 30 °C /h (this process takes around 1 h to 1 h 30 min depending upon outside temperature); and
b) In the case of curing under high pressure steam in autoclaves, the temperature and pressure are gradually built up during a period of about 4 h.

11.5.2.6 The third stage of steam curing is to maintain the uniform temperature and pressure for a duration depending upon thickness of the section. This may vary from 3 h to 5½ h in the case of low pressure steam curing and 4 h to 7 h in the case of high pressure steam curing.

11.5.2.7 The fourth stage of steam curing is the gradual cooling down of concrete products and surroundings in the chamber and normalization of the pressure to bring it at par with outside air. The maximum cooling rate, which is dependent on the thickness of the member, should normally not exceed 30 °C/h.

11.5.3 In all these cases, the difference between the temperature of the concrete product and the outside temperature should not be more than 60 °C for concretes up to M30 and 75 °C for concretes greater than M45. In the case of light weight concrete, the difference in temperature should not be more than 60 °C for concretes less than M25. For concretes greater than M50, the temperature differences can go up to 75 °C.

11.6 Stacking During Transport and Storage

Every precaution shall be taken against overstress or damage, by the provision of suitable packings at agreed points of support. Particular attention is directed to the inherent dangers of breakage and damage caused by supporting other than at two positions, and also by the careless placing of packings (for example, not vertically one above the other). Ribs, corners and intricate projections from solid section should be adequately protected. Packing pieces shall not discolour, disfigure or otherwise permanently cause mark on units or members. Stacking shall be arranged or the precast units should be protected, so as to prevent the accumulation of trapped water or rubbish and, if necessary, to reduce the risk of efflorescence.

11.6.1 The following points shall be kept in view during stacking:

a) Care should be taken to ensure that the flat elements are stacked with right side up. For identification, top surfaces should be clearly marked.

b) Stacking should be done on a hard and suitable ground to avoid any sinking of support when elements are stacked.

c) In case of horizontal stacking, packing materials shall be at specified locations and shall be exactly one over the other to avoid cantilever stress in panels.

d) Components should be packed in a uniform way to avoid any undue projection of elements in the stack which normally is a source of accident.

e) In general, vertical stacking should be limited to 6-10 components. Where the ground is only compacted, the maximum ground load at support should be restricted to 15 t/m^2 and the stacking should be restricted to 6 panels. Where PCC layer is poured, the maximum ground load at support should be restricted to 30 t/m^2 and the stacking should be restricted to 10 panels. In both cases, the ground should be fairly levelled and the supports should be continuous along the width of the panels.

f) All wall panels shall be stacked, preferably symmetrically on both sides, against steel A-frames. The slope of the sides of A-frame shall be between 75° and 80° to the horizontal and the bottom of the frame shall be provided with concrete footings to resist component of self-weight and also horizontal wind pressure on the wall panel. Similar type of A-frames should be used for transporting wall panels.

11.7 Handling Arrangements

11.7.1 Lifting and handling positions shall be clearly defined particularly where these sections are critical. Where necessary special facilities, such as bolt holes or projecting loops, shall be provided in the units and full instructions supplied for handling. For the purpose of testing the bolts/hooks, bond strength shall be the criteria for embedded bolts and bearing strength for through bolts. For bond strength, pull out test of concrete shall be carried out. *See* **11.11** for additional design considerations.

11.7.2 For precast pre-stressed concrete members, the residual pre-stress at the age of particular operation of handling and erection shall be considered in conjunction with any stresses caused by the handling or erection of member. The compressive stress thus computed shall not exceed 50 percent of the cube strength of the concrete at the time of handling and erection. Tensile stresses upto a limit of 50 percent above those specified in IS 456 shall be permissible.

11.8 Identification and Marking

All precast units shall bear an indelible identification, location and orientation marks as and where necessary. The date of manufacture shall also be marked on the units.

11.8.1 The identification markings on the drawings shall be the same as that indicated in the manufacturer's literature and shall be shown in a tabular format on the setting schedule together with the length, type, size of the unit, and the sizes and arrangement of all reinforcement.

11.9 Transport

Transport of precast elements inside the factory and to the site of erection is of considerable importance not only from the point of view of economy but also from the point of view of design and efficient management. Transport of precast elements must be carried out with extreme care to avoid any jerk and distress in elements and handled as far as possible in the same orientation as it is to be placed in final position. *See* **11.11** for additional design considerations.

11.9.1 *Transport Inside the Factory*

Transport of precast elements moulded inside the factory depends on the method of production, selected for the manufacture as given in Table 3.

11.9.2 *Transport from Stacking Yard Inside the Factory to the Site of Erection*

Transport of precast concrete elements from the factory to the site of erection should be planned in such a way so as to be in conformity with the traffic rules and regulations as stipulated by the Authorities. The size of the elements is often restricted by the availability of suitable transport equipment, such as tractor-*cum*-trailers, to suit the load and dimensions of the member in addition to the opening dimensions under the bridge and load carrying capacity while transporting the elements over the bridge.

11.9.2.1 While transporting elements in various systems, that is, wagons, trucks, bullock carts, etc, care should be taken to avoid excessive cantilever actions and desired supports are maintained. Transportation of prefabricated element should be carried out with care. Care should be taken to also protect the steel inserts and reinforced bars of the precast elements during transportation. Precast elements should be secured with safety ties so as to ensure that vibrations to the elements in transit are minimum. Special care should be taken at location of sharp bends and on uneven or slushy roads to avoid undesirable stresses in elements.

11.9.2.2 Before loading the elements in the transporting media, care should be taken to ensure that the base packing for supporting the elements are located at specified positions only. Subsequent packings shall be kept strictly one over the other.

11.10 Erection

The tower crane or other mobile cranes have different lifting capacities at various radii; maximum weight at a radius near to the centre and minimum weight at a radius farther from centre. In order to minimize the number of precast elements, the crane selected should be capable of handling heaviest precast elements at its maximum radius. The floor plan should indicate weight of panels at different radii of crane matching with the lifting capacity of crane at each radius.

In the erection of precast elements, all the following items of work are meant to be included:

a) Slinging of the precast element;
b) Tying up of erection ropes connecting to the erection hooks;
c) Cleaning of the elements and the site of erection;
d) Cleaning of the steel inserts before incorporation in the joints, lifting up of the elements, setting them down into the correct envisaged position;
e) Adjustment to get the stipulated level, line and plumb by means of levelling bolts and adjustable props;
f) Welding of cleats;
g) Changing of the erection tackles;
h) Putting up and removing of the necessary scaffolding or supports;
j) Welding of the inserts, laying of reinforcements in joints and grouting the joints; and
k) Finishing the joints to bring the whole work to a workmanlike finished product.

See **11.11** for additional design considerations.

11.10.1 In view of the fact that the erection work in various construction jobs using prefabricated concrete elements differs from place to place depending on the site conditions, safety precautions in the work are of utmost importance. Hence, only those skilled foremen, trained workers and fitters who have been properly instructed about the safety precautions to be taken should be employed on the job. For additional information, *see* relevant Indian Standards for safety during construction.

11.10.2 Transport of people, workers or visitors, by using cranes and hoists should be strictly prohibited on an erection site.

11.10.3 In the case of tower rail mounted cranes running on rails, the track shall not have a slope more than 0.2 percent in the longitudinal direction. In the transverse direction, the rails shall lie in a horizontal plane.

11.10.4 The track of the crane should be checked daily to see that all fish plates and bolts connecting them to the sleepers are in place and in good condition.

11.10.5 The operation of all equipment used for handling and erection shall follow the operations manual provided by the manufacturer. All safety precautions shall be taken in the operations of handling and erection.

11.10.6 *Erection Tolerances*

For the erection tolerances, reference shall be made to IS 11447 for large panel prefabricates.

11.11 Design Considerations

Based on the design intent, production environment and aesthetic requirements of the prefabricated panels, the resultant stresses should be controlled to minimize cracking in precast and/or prestressed panels. Precast (non-prestressed) components are generally designed as 'cracked' unless cracking is an aesthetic concern. Where the panels are to be designed 'without cracking' the extreme fibre tensile stresses during various stages of handling, storage and erection should be kept under the tensile strength of the concrete (modulus of rupture) at that stage with a factor of safety of 1.5 or more.

> Resultant extreme fibre tensile stresses $\leq 0.7\sqrt{f_{ck}}/1.5$, where f_{ck} is the characteristic strength of concrete, in N/mm^2

Structural design requirements of minimum spacing, skin reinforcement and crack width criteria as specified in IS 456 are applicable.

Lifting hooks should be located such that while lifting the panel, minimum bending moments are produced.

In addition, extra static load multipliers should be used to account for impact, and demoulding forces as per the following:

Sl No. (1)	*Prefabricated Panel Type* (2)	*Static Load Multiplier* (3)
i)	*Demoulding*:	
	a) Structural components	1.3
	b) Architectural components	1.4
ii)	*Yard handling and erection*:	
	All components	1.2
iii)	*Transportation*:	
	All components	1.2

The static load multipliers are to be used in addition to the factor of safety of 1.5 used in the tensile stress limit. Also, the load multipliers are only needed for the flexural design and are not applicable for the lifting devices.

Lifting hooks shall be designed for,

a) self weight of panel plus an adhesive force, varying between 1.5 to 3.0 kN/m^2, depending upon the surface condition of the mould; or
b) 1.3 times self-weight of panel, whichever is more.

12 EQUIPMENT

12.1 General

The equipment used in the precast concrete industry/construction may be classified into the following categories:

a) Machinery required for quarrying of coarse and fine aggregates;
b) Conveying equipment, such as belt conveyors, chain conveyors, screw conveyors, bucket elevators, hoists, etc;
c) Concrete mixing machines;
d) Concrete vibrating machines;
e) Erection equipment, such as cranes, derricks, hoists, chain pulley blocks, etc;
f) Transport machinery, such as tractor-*cum*-trailers, dumpers, lorries, locomotives, motor boats and rarely even helicopters;
g) Workshop machinery for making and repairing steel and timber moulds;
h) Bar straightening, bending and welding machines to make reinforcement cages;
j) Minor tools and tackles, such as wheel barrows, concrete buckets, etc; and
k) Steam generation plant for accelerated curing.

In addition to the above, pumps and soil compacting machinery are required at the building site for the execution of civil engineering projects involving prefabricated components.

Each of the above groups may further be classified into various categories of machines and further to various other types depending on the source of power and capacity.

12.2 Mechanization of the Construction and Erection Processes

The various processes can be mechanized as in any other industry for attaining the advantages of mass production of identical elements which, in turn, will increase productivity and reduce the cost of production in the long run, at the same time guaranteeing quality for the end product. On the basis of the degree of mechanization used, the various precasting factories can be divided into three categories:

a) With simple mechanization;
b) With partial mechanization; and
c) With complex mechanization leading to automation.

12.2.1 In simple mechanization, simple mechanically operated implements are used to reduce the manual labour and increase the speed.

12.2.2 In partial mechanization, the manual work is more or less eliminated in the part of a process. For example, the batching plant for mixing concrete, hoists to lift materials to a great height and bagger and bulldozer to do earthwork come under this category.

12.2.3 In the case of complex mechanization leading to automation, a number of processes leading to the end product are all mechanized to a large extent (without or with a little manual or human element involved). This type of mechanization reduces manual work to the absolute minimum and guarantee the mass production at a very fast rate and minimum cost.

12.2.4 For equipment, *see* relevant Indian Standards.

13 PREFABRICATED STRUCTURAL UNITS

For the design and construction of composite structures made up of prefabricated structural units and cast *in-situ* concrete, reference may be made to IS 3935.

For design and construction of precast reinforced and prestressed concrete triangulated trusses, reference may be made to IS 3201.

For design and construction of floors and roofs using various precast units, reference may be made to IS 6332, IS 10297, IS 10505, IS 13994, IS 14142, IS 14215 and IS 14242.

For construction with large panel prefabricates, reference may be made to IS 11447.

For construction of floors and roofs with joists and filler blocks, reference may be made to IS 6061 (Parts 1 to 4).

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
456 : 2000	Plain and reinforced concrete — Code of practice (*fourth revision*)
875	Code of practice for design loads (Other than earthquake) for buildings and structures
(Part 1) : 1987	Dead loads — Unit weights of building materials and stored materials (*second revision*)
(Part 2) : 1987	Imposed loads (*second revision*)
(Part 3) : 2015	Wind loads (*third revision*)
(Part 4) : 1987	Snow loads (*second revision*)
(Part 5) : 1987	Special loads and combinations (*second revision*)
1343 : 2012	Prestressed concrete — Code of practice (*second revision*)
1893 (Part 1) : 2016	Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (*sixth revision*)
2185	Specification for concrete masonry units
(Part 1) : 2005	Hollow and solid concrete blocks (*third revision*)
(Part 2) : 1983	Hollow and solid lightweight concrete blocks (*first revision*)
(Part 3) : 1984	Autoclaved cellular (aerated) concrete blocks (*first revision*)
(Part 4) : 2008	Cellular concrete blocks using preformed foam
3201 : 1988	Criteria for design and construction of precast trusses and purlins (*first revision*)
3935 : 1966	Code of practice for composite construction
4082 : 1996	Stacking and storage of construction materials and components at site — Recommendations (*second revision*)
4905 : 2015	Random sampling and randomization procedures (*first revision*)
6061	Code of practice for construction of floor and roof with joists and filler blocks
(Part 1) : 1971	With hollow concrete filler blocks
(Part 2) : 1981	With hollow clay filler blocks (*first revision*)
(Part 3) : 1981	With precast hollow clay block joists and hollow clay filler blocks
(Part 4) : 1981	With precast hollow clay block slab panels
6072 : 1971	Specification for autoclaved reinforced cellular concrete wall slabs
6073 : 2006	Autoclaved reinforced cellular concrete floor and roof slabs-Specification (*first revision*)
6332 : 1984	Code of practice for construction of floor and roofs using precast doubly-curved shell units (*first revision*)
9893 : 1981	Specification for precast concrete blocks for lintels and sills
10297 : 1982	Code of practice for design and construction of floors and roofs using precast reinforced/ prestressed concrete ribbed or cored slab unit
10505 : 1983	Code of practice for construction of floors and roofs using precast concrete waffle units
11447 : 1985	Code of practice for construction with large panel prefabricates
12440 : 1988	Specification for precast concrete stone masonry blocks
13990 : 1994	Specification for precast reinforced concrete planks and joists for flooring and roofing
13994 : 1994	Code of practice for design and construction of floor and roof with precast reinforced concrete planks and RC joists
14142 : 1994	Code of practice for design and construction of floors and roofs with prefabricated brick panel

IS No.	*Title*
14143 : 1994	Specification for prefabricated brick panel and partially precast concrete joist for flooring and roofing
14201 : 1994	Specification for precast reinforced concrete channel unit for construction of floors and roofs
14215 : 1994	Code of practice for construction of floor and roof with RC channel units
14241 : 1995	Specification for precast L-Panel units for roofing
14242 : 1995	Code of practice for design and construction of roof with L-Panel units

ANNEX B

(*Foreword*)

COMMON DEFECTS AND REMEDIES

B-1 As defects in precast concrete elements result in direct and indirect cost in terms of rectification and construction time, it is worthwhile to ensure that they are produced and handled in a way to avoid/reduce such incidences. Table 4 illustrates some of these common defects, their causes and preventive measures.

Table 4 List of Common Defects and Recommended Measures

(*Clause* B-1)

Sl No. (1)	Common Defects (2)	Possible Causes (3)	Recommendations (4)	Remedial Measures (5)
i)	*Dimensional deviation*: a) Variation in the dimension of precast elements would affect the joint alignment between these elements when erected b) Precast slab element may warp due to insufficient concrete strength at lifting or improper storage condition	a) Mould forms may not be sufficiently rigid to maintain specified tolerances during concrete placement b) Precast elements may not have gained sufficient concrete strength when demoulded c) Top surface finish of precast elements may not be properly levelled and troweled during production which result in differential thickness d) Precast elements (especially slender wall or slab panels)may be subjected to undue stress and deformation when they are not properly supported during storage	a) Regular check on the dimensions and rigidity of mould forms before casting operations As a general guide the recommended thickness for steel mould are: 1) 4.5 mm – upto 50 castings, 2) 6 mm – upto 100 castings, and 3) 9 mm – upto 200 castings Mould forms conditions will deteriorate with time and usage. They should be repaired, stiffened or replaced when needed b) Cube tests should be conducted to ascertain the concrete strength of elements before demoulding c) Spreading and levelling of concrete placement using appropriate tools such as screeder d) Precast elements should be properly stored and stacked at designated points using suitable support spacers and frame rack system	a) For minor deviation, corrective measures such as surface grinding, trimming/ hacking and skim coat application can be appropriately used to remedy the situation b) Precast elements that are not within acceptable tolerance limits and have significant effects on the structural integrity or architectural performance should not be used
ii)	Cracks	a) Precast elements may not have gained sufficient concrete strength before demoulding b) Cracks may have occurred during initial lifting due to friction between the elements and the casting mould forms c) Thickness of the precast elements may be too thin (70 mm or less) and flimsy for safe demoulding and handling d) Cracks may have occurred during erection due to lack of planning and provisions given to the precast panel geometry, crane rigging configuration and location of openings	a) Proper curing method, curing time and temperature should be maintained b) Cube tests should be conducted to ascertain the concrete strength of elements before demoulding c) Appropriate form release agents should be used and uniformly applied onto the mould surface to minimize friction d) Sectional thickness of precast elements should be increased to accommodate demoulding and handling stresses e) Proper handling techniques should be adopted f) Sufficient lifting points should be used to minimize over-stressing on certain areas g) Additional reinforcing bars should be placed around the opening and odd corners h) Temporary stiffeners for openings should be provided during erection	a) All cracks should be examined by a qualified engineer to determine if they present a structural problem b) Depending on the locations and seriousness of the cracks, different repair methods can be used to make good the affected precast elements c) Hairline cracks (not more than 0.3mm) can be repaired by cutting V-groove of specified minimum depth along the crack-lines, followed by patching subject to location and length of the crack in relation to length of units and not having adverse effect on the structural strength of the unitd) For surface cracks (more than 0.3mm) or through cracks, epoxy injection method should be used to ensure that the cracks are completely bound and filled with epoxy

Table 4 (*Continued*)

Sl No. (1)	Common Defects (2)	Possible Causes (3)	Recommendations (4)	Remedial Measures (5)
iii)	Chip-off and damages	a) Chip-off at panel edges are usually caused by the hard bearing at supports or excessive force exerted on the elements when handling b) Improper storage method	a) Precautions should be taken to avoid damaging the elements in the course of placement on vehicle, travel to site and during the unloading operation. Bearing pads should be used to cushion the contact areas from damage b) The storage area should be relatively flat and dry c) Precast elements should be properly stored and stacked at designated points using suitable support spacers and frame rack system d) The casting slab or mould form should be thoroughly cleansed, levelled to achieve a smooth surface e) The coverage of form release agents should be adequate and uniformly applied onto the mould surface f) Spacers of the correct sizes should be used and well secured to maintain the concrete cover required during casting g) Lifting inserts and concrete strength of elements should be of adequate capacity for the intended lift. Use lifting proprietary products for safe and efficient handling h) Lifting inserts or hooks should be inspected for proper location. They should be fastened to specified depth prior to concrete placement	a) Remove all loose concrete and wash off any dust or dirt in the affected area b) Apply bonding agent to affected concrete surface c) Welded wire mesh can be included to provide support for the patch mix concrete or grout d) Patch mix composition or grout should be consistent with the strength requirements of the adjacent concrete e) Formwork is to be put up where necessary to contain the patch mix or grout f) Protect the affected area from any disturbance during curing period
iv)	Honeycomb and excessive pinholes	a) Poor concrete compaction due to ineffective vibration or rebars congestion b) Grout leakage along the perimeter side forms due to: 1) Loose or missing bolts, fixing pins 2) Damaged rubber gasket seal 3) Mould part, if defective	a) Proper compaction method should be adopted and carried out b) Concrete mix design and workability should be reviewed and adjusted when needed c) Appropriate concrete vibrator such as clamp-on form vibrator can be used to attain better compaction d) Rebar congestion can be alleviated by having larger (that is, lesser) rebars or by increasing the sectional dimensions of the elements where possible e) Mechanical couplers or sleeves can be used to simplify the reinforcement layout and to minimize rebar congestion f) Defective mould forms and accessories should be repaired or replaced to prevent grout leakage during concreting	a) Remove all loose concrete and wash off any dust or dirt in the affected area b) Apply bonding agent to affected concrete surface c) Welded wire mesh can be included to provide support for the patch mix concrete or grout d) Patch mix composition or grout should be consistent with the strength requirements of the adjacent concrete e) Formwork is to be put up where necessary to contain the patch mix or grout f) Protect the affected area from any disturbance during curing period

Table 4 (*Concluded*)

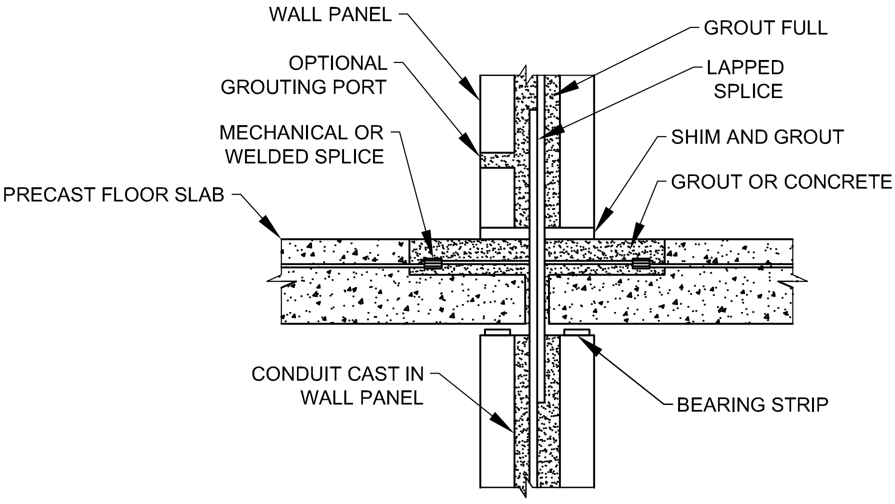
Sl No. (1)	Common Defects (2)	Possible Causes (3)	Recommendations (4)	Remedial Measures (5)
v)	Missing or wrong details such as cast-in items, architectural nib and groove details, lifting hooks, reinforcement/starter bars/block-out/corrugated pipes	a) Items may not have been included in the shop drawing b) Quality checks may not be properly in place	a) All items should be reflected in the shop drawings for production. Any changes should be made known to the production team b) The use of checklists during inspection can help to ensure that all items specified in the drawing are included before casting	a) Certain details such as missing starter bars/reinforcement and lifting hooks can be replaced by welding additional reinforcement bars after hacking off the concrete at the affected area b) Other items such as cast-in items, groove and block-out can be provided by chasing or chiseling out the face of the precast panels
vi)	Strand slippage which exceed allowable design values (item applicable to pre-stressed elements only) Slippages of pre-stressing strands can be detected by visual inspection	a) Insufficient bond strength between concrete and the pre-stressing strands b) Poor compaction of concrete around pre-stressed strands	a) Required concrete strength of the precast elements should be attained and verified by cube test results before de-tensioning of strands b) Proper compaction method should be adopted and carried out during casting c) Concrete mix design and workability should be reviewed and adjusted when needed d) Provision of appropriate concrete vibrator to attain better compaction	a) It is not possible to rectify the elements from strand slippage b) Design verification should be carried out to ascertain the reduced capacity of the elements due to slippage, if adopted
vii)	Alignment	a) Inaccurate setting out and positioning of precast elements during erection b) Deviation in the dimensions of the precast element	a) Appropriate surveying and levelling equipment should be used to achieve better alignment b) Required alignment and level should be confirmed before permanent jointing c) Critical dimensions of precast concrete elements should be verified before installation	a) Minor adjustments of the element/panel alignment can be done during installation However the effects on the final alignment and deviation of the building should be evaluated b) For minor deviations, corrective measures such as surface grinding, trimming/hacking and skim coat application can be appropriately used to rectify the precast elements before installation c) Precast elements that are not within acceptable tolerance limits and have significant effects on the structural integrity or architectural performance should not be used

ANNEX C

(*Clause* 9.4)

COMMON PRECAST JOINT CONNECTIONS

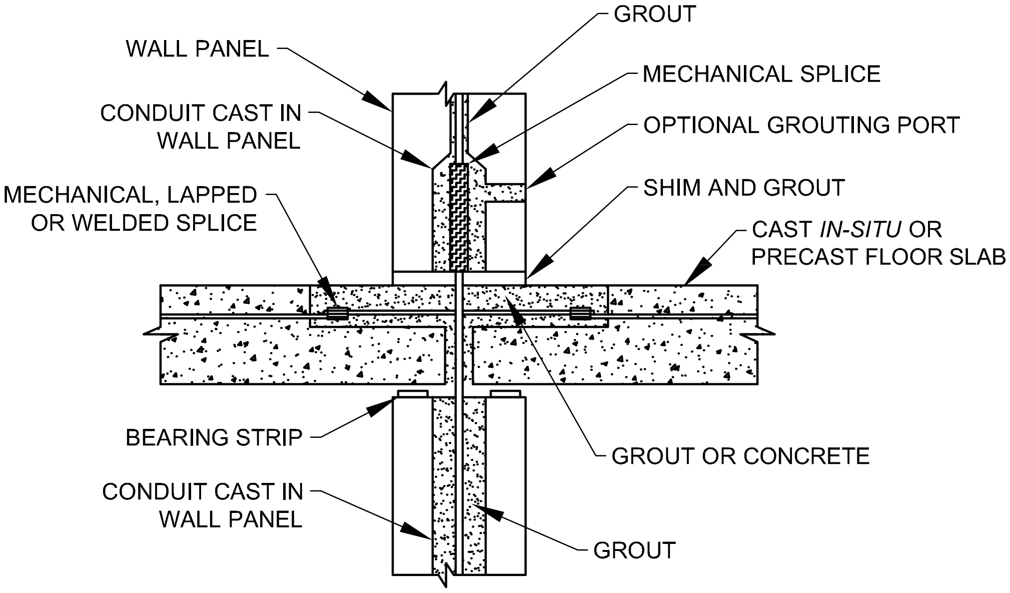
C-1 Typical figures of some common precast joint connections are given in Fig. 10 to Fig. 27.



SECTION AT JOINT

NOTE – Overlapping bars in grout-filled conduit are extended full-height through the structural element

Fig. 10 Lapped Splices in Large Conduit


WALL PANEL
CONDUIT CAST IN WALL PANEL
MECHANICAL, LAPPED OR WELDED SPLICE
BEARING STRIP
CONDUIT CAST IN WALL PANEL
GROUT
MECHANICAL SPLICE
OPTIONAL GROUTING PORT
SHIM AND GROUT
CAST IN-SITU OR PRECAST FLOOR SLAB
GROUT OR CONCRETE
GROUT

NOTE – Vertical bars in conduit are spliced and the system is grouted

Fig. 11 Mechanical Connection in Conduit

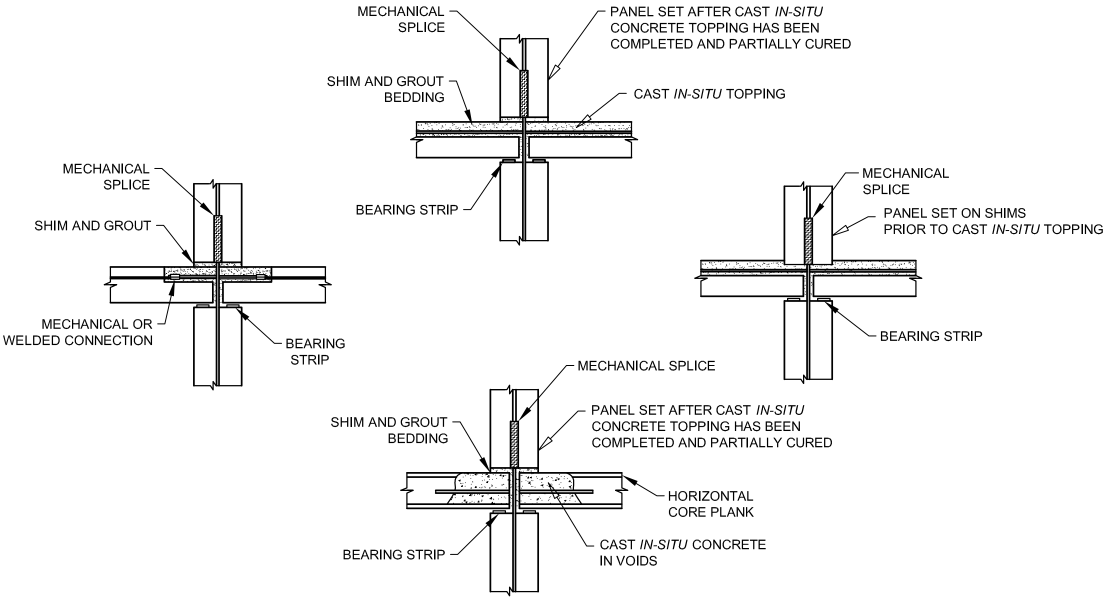

MECHANICAL SPLICE
PANEL SET AFTER CAST *IN-SITU* CONCRETE TOPPING HAS BEEN COMPLETED AND PARTIALLY CURED
SHIM AND GROUT BEDDING
CAST *IN-SITU* TOPPING
BEARING STRIP
MECHANICAL SPLICE
SHIM AND GROUT
MECHANICAL OR WELDED CONNECTION
BEARING STRIP
MECHANICAL SPLICE
PANEL SET ON SHIMS PRIOR TO CAST *IN-SITU* TOPPING
BEARING STRIP
MECHANICAL SPLICE
SHIM AND GROUT BEDDING
PANEL SET AFTER CAST *IN-SITU* CONCRETE TOPPING HAS BEEN COMPLETED AND PARTIALLY CURED
HORIZONTAL CORE PLANK
BEARING STRIP
CAST *IN-SITU* CONCRETE IN VOIDS

FIG. 12 DIFFERENT TYPES OF MECHANICAL SPLICES FOR CONNECTION OF VARIOUS CONIFIGURATIONS OF PRECAST WALLS AND FLOORS

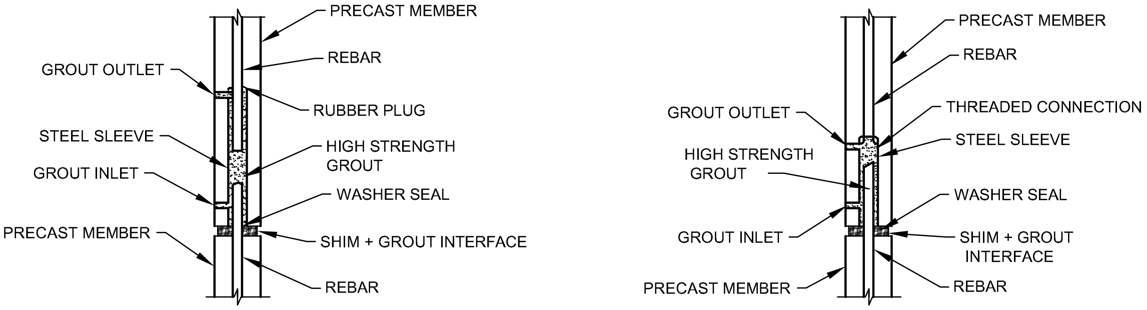


FIG. 13 SOME MECHANICAL SPLICES USING HIGH-STRENGTH NON-SHRINK GROUT

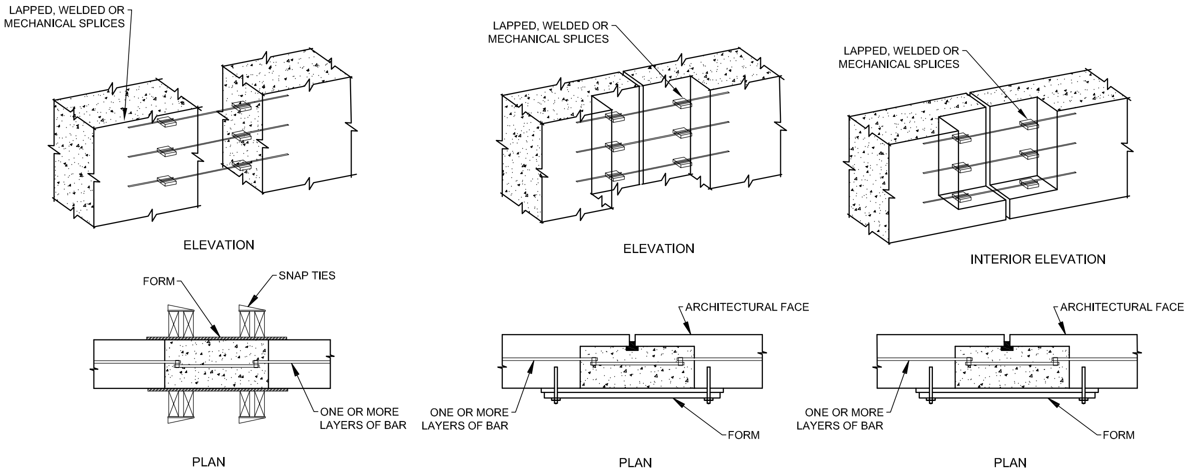

LAPPED, WELDED OR MECHANICAL SPLICES
ELEVATION
LAPPED, WELDED OR MECHANICAL SPLICES
ELEVATION
LAPPED, WELDED OR MECHANICAL SPLICES
INTERIOR ELEVATION
FORM
SNAP TIES
ONE OR MORE LAYERS OF BAR
PLAN
ARCHITECTURAL FACE
ONE OR MORE LAYERS OF BAR
FORM
PLAN
ARCHITECTURAL FACE
ONE OR MORE LAYERS OF BAR
FORM
PLAN

FIG. 14 VARIATIONS OF SPLICES AND CASTIN-SITU CLOSURE PLACEMENTS TO CREATE VERTICAL JOINTS BETWEEN PRECAST CONCRETE ELEMENTS

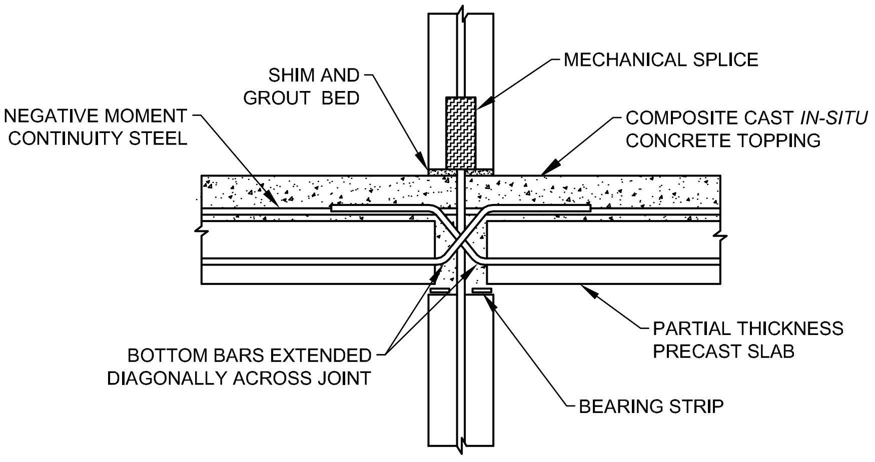
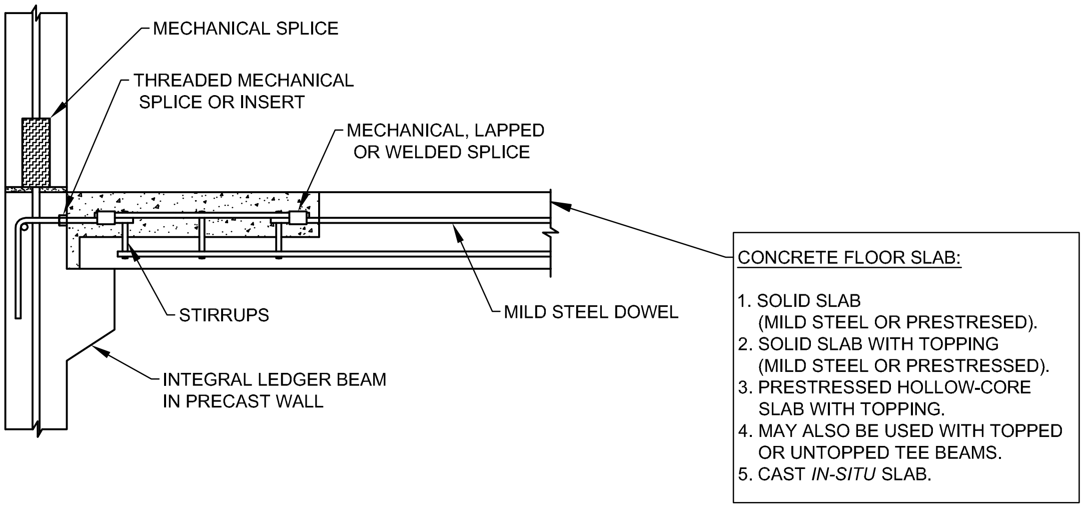

MECHANICAL SPLICE
SHIM AND GROUT BED
NEGATIVE MOMENT CONTINUITY STEEL
COMPOSITE CAST *IN-SITU* CONCRETE TOPPING
PARTIAL THICKNESS PRECAST SLAB
BOTTOM BARS EXTENDED DIAGONALLY ACROSS JOINT
BEARING STRIP

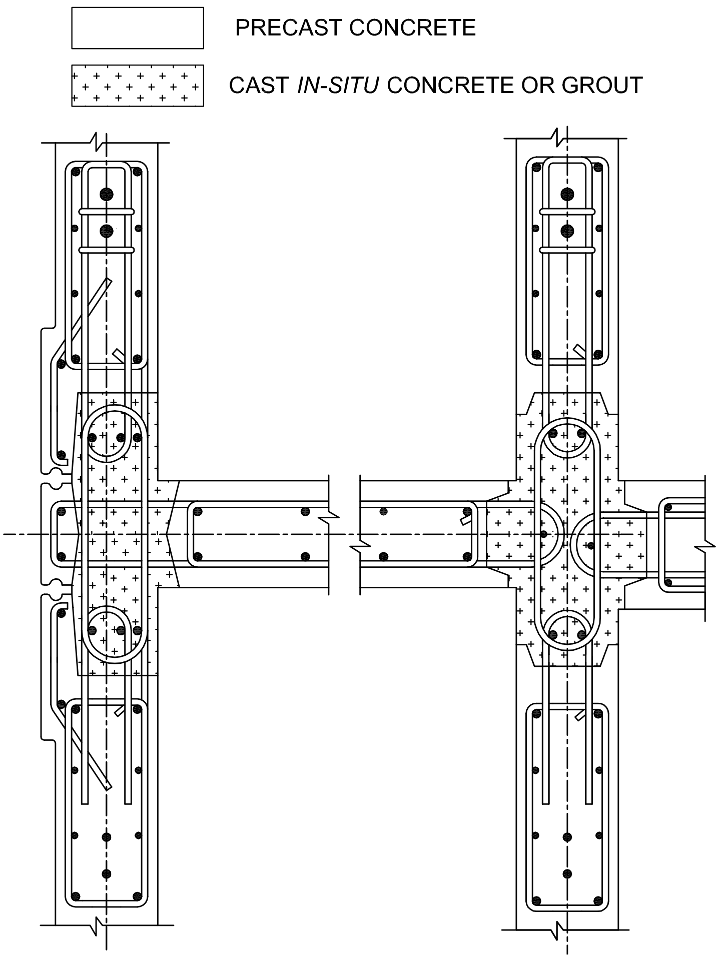
FIG. 15 FLOOR SLAB-TO-WALL DETAIL WHERE DIAGONAL DOWELS CROSS THE WALL JOINT INTO THE OPPOSITE FLOOR


MECHANICAL SPLICE
THREADED MECHANICAL SPLICE OR INSERT
MECHANICAL, LAPPED OR WELDED SPLICE
STIRRUPS
MILD STEEL DOWEL
INTEGRAL LEDGER BEAM IN PRECAST WALL

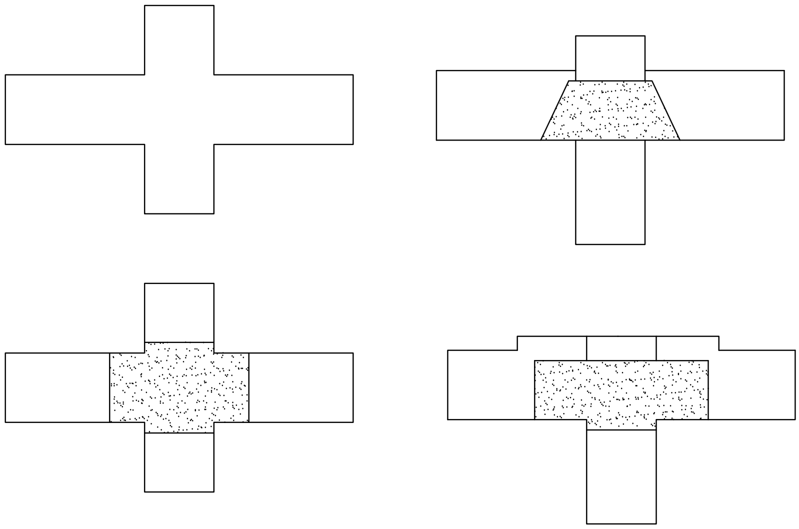
CONCRETE FLOOR SLAB:

1. SOLID SLAB (MILD STEEL OR PRESTRESED).
2. SOLID SLAB WITH TOPPING (MILD STEEL OR PRESTRESSED).
3. PRESTRESSED HOLLOW-CORE SLAB WITH TOPPING.
4. MAY ALSO BE USED WITH TOPPED OR UNTOPPED TEE BEAMS.
5. CAST *IN-SITU* SLAB.

FIG. 16 END DETAIL OF A MONOLITHIC CONNECTION BETWEEN PRECAST CONCRETE FLOOR ELEMENT AND A PRECAST CONCRETE WALL

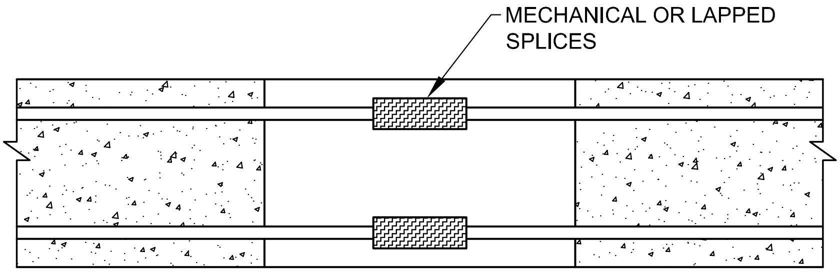


17A PLAN VIEW OF TYPICAL GROUTED OR CAST *IN-SITU* VERTICAL JOINTS IN SHEAR-WALL PANELS REINFORCED FOR HIGH SEISMIC LOADING (REFER FIG. 17B FOR PLAN VIEW FOR DIFFERENT CONFIGURATIONS)

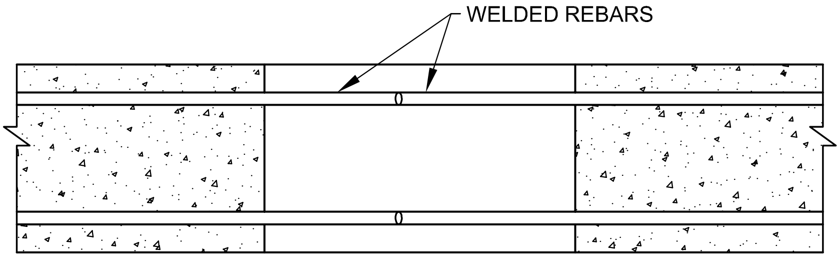


17B VARIATIONS OF VERTICAL WALL-TO-WALL CONNECTIONS (PLAN VIEWS)

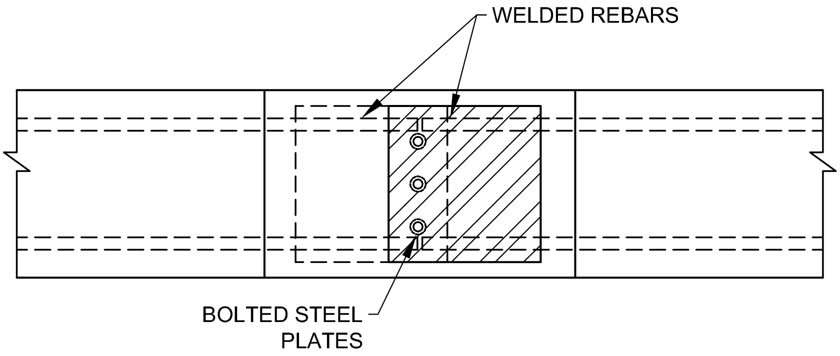
FIG. 17 VERTICAL JOINTS IN SHEAR-WALL PANELS REINFORCED FOR HIGH SEISMIC LOADING



18A USING MECHANICAL OR LAPPED SPLICES



18B BUTT-WELDED REINFORCEMENT (SPECIAL PROCESS)



18C COMBINATION OF BOLTED PLATES AND WELDED REBARS

Fig. 18 Horizontal Connections Between Beam or Girder Ends at Locations Other Than Column Faces

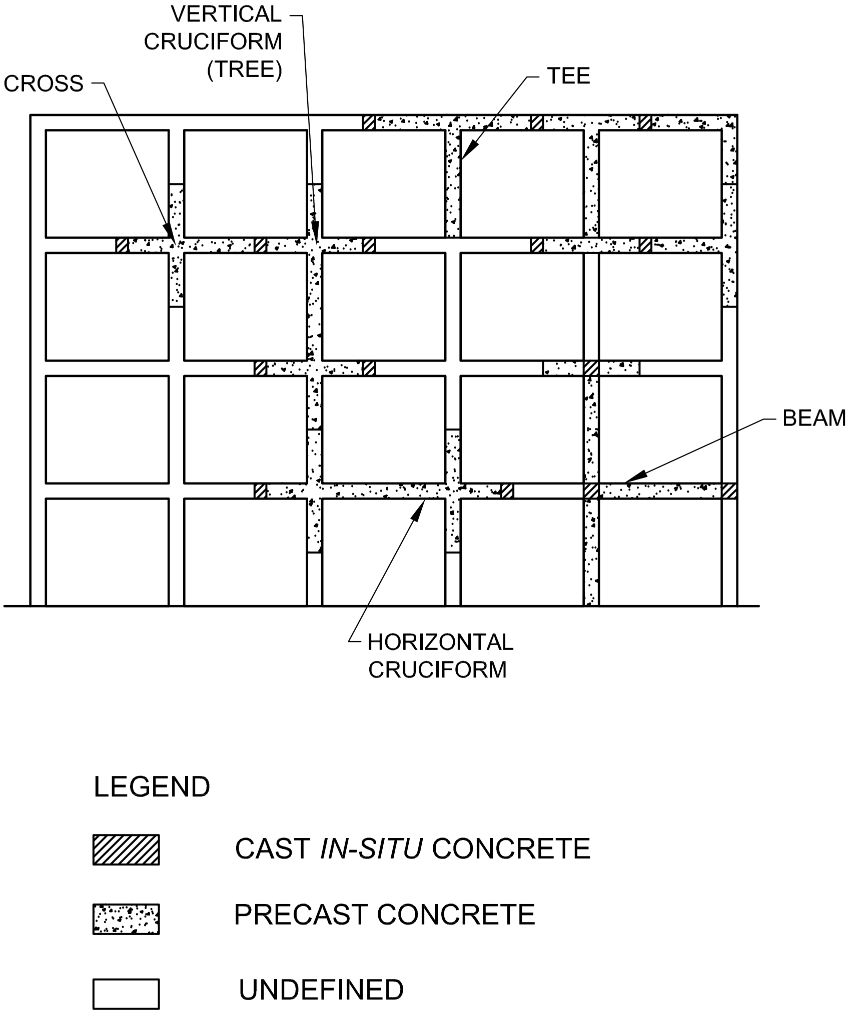


Fig. 19 Various Configurations of Precast Frame Elements

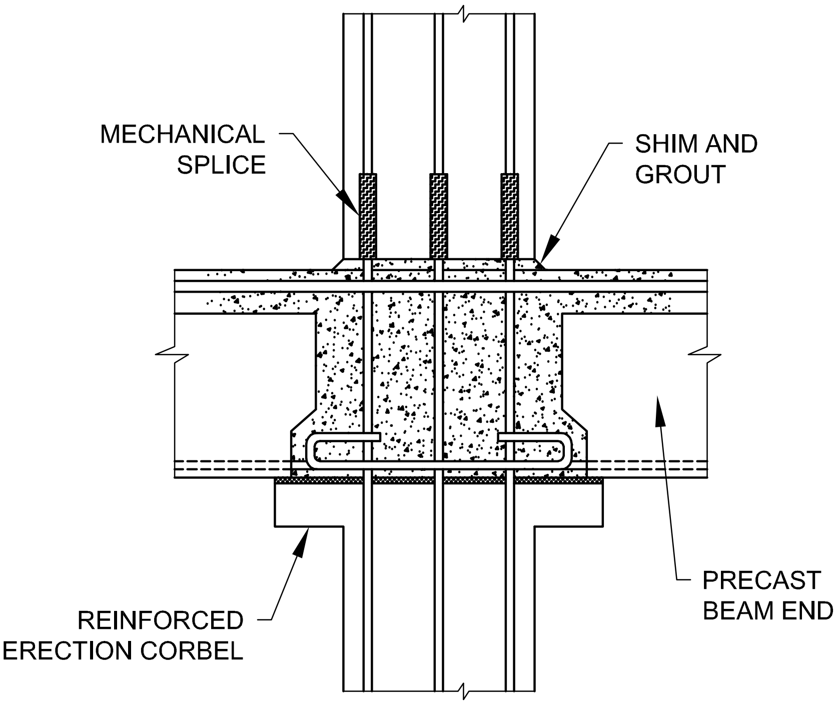
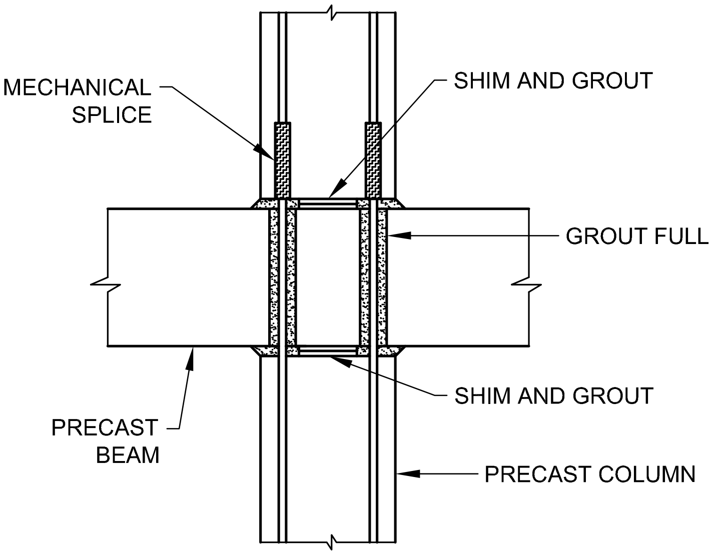


FIG. 20 CONNECTION AT BEAMS AND COLUMNS WITH CAST *IN-SITU* CLOSURE



NOTE – Conduit diameter shoule be two to four times the bar diameter for tolerance in field erection

FIG. 21 COLUMN-TO-COLUMN CONNECTION THROUGH CONDUITS INSTALLED IN A BEAM

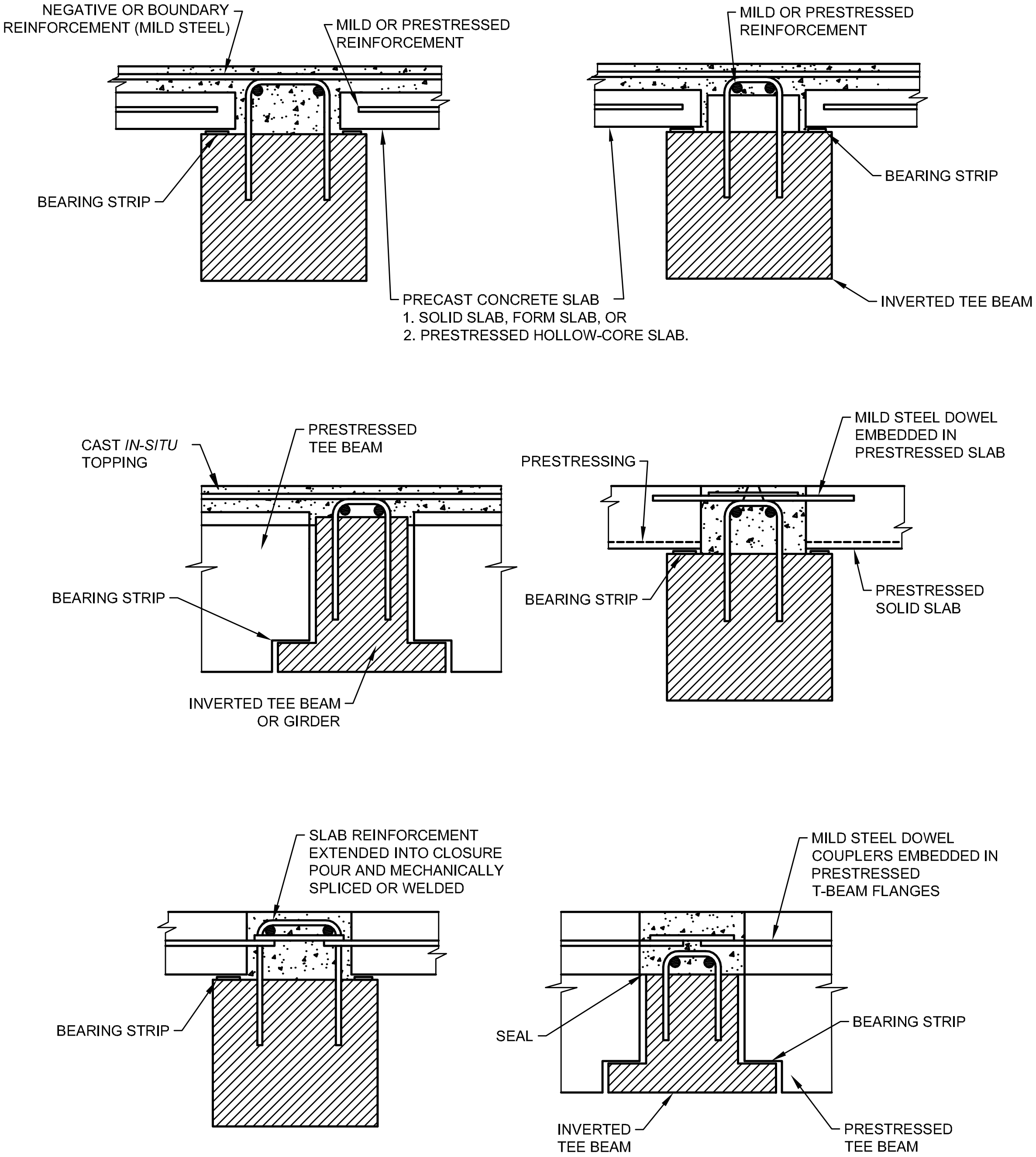
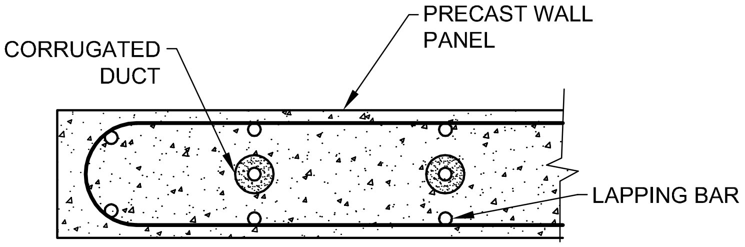
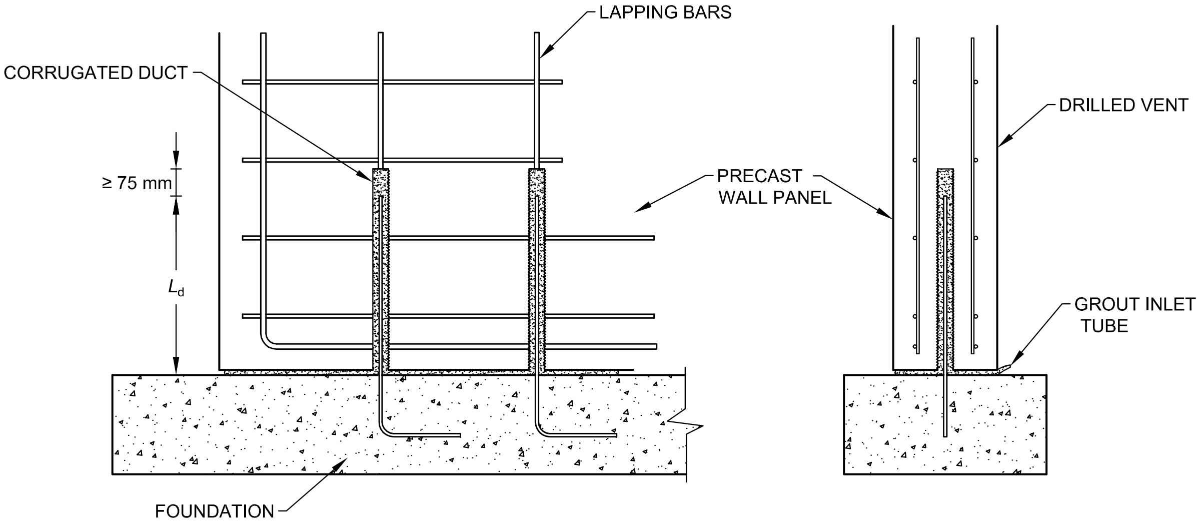


Fig. 22 Typical End Connections of Precast Concrete Floor Slab Elements



23A HORIZONTAL CROSS-SECTION



23B ELEVATION

23C VERTICAL CROSS-SECTION

FIG. 23 WALL-FOUNDATION BEAM CONNECTION THROUGH GROUTED DUCTING

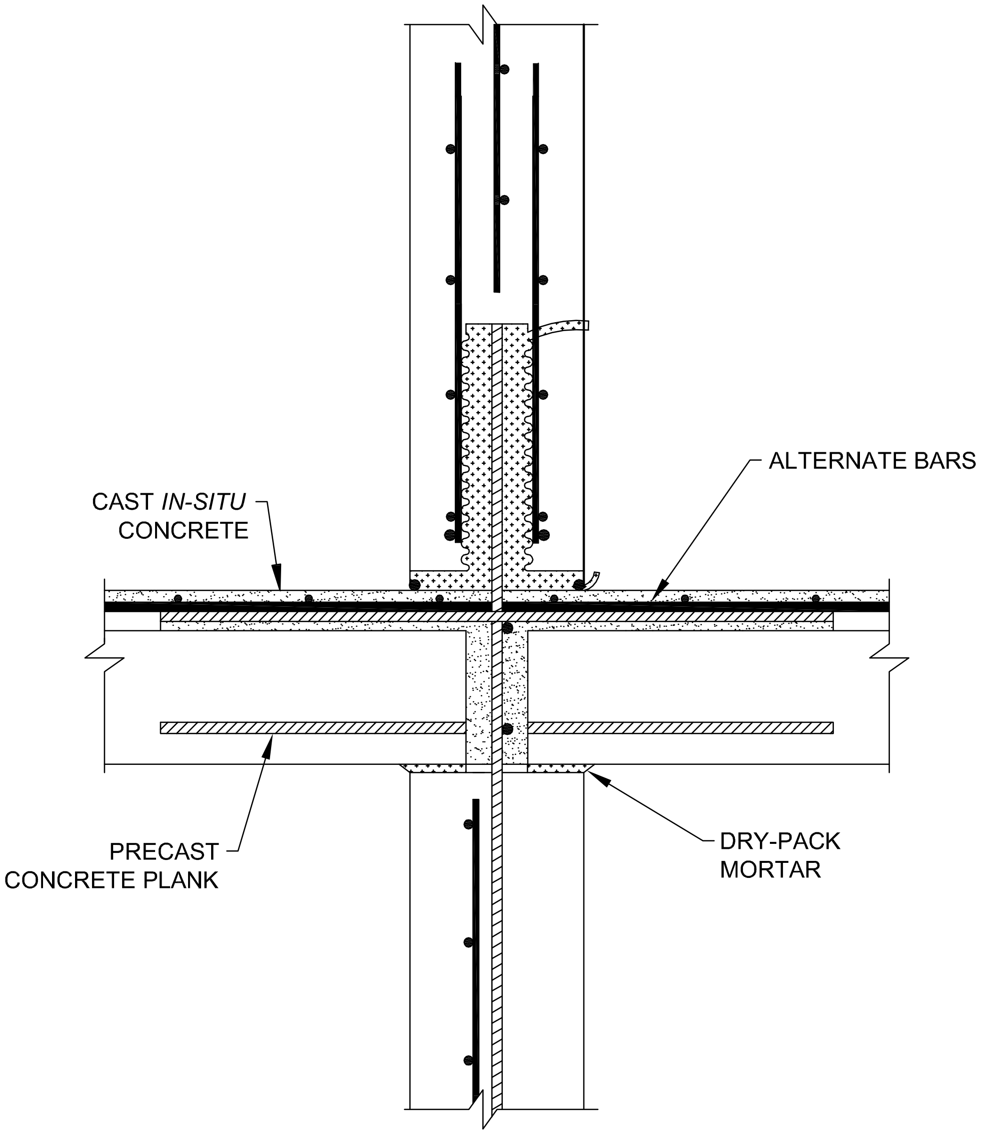


FIG. 24 INTERIOR WALL-FLOOR SLAB CONNECTION DETAIL CONTINUOUS WALL

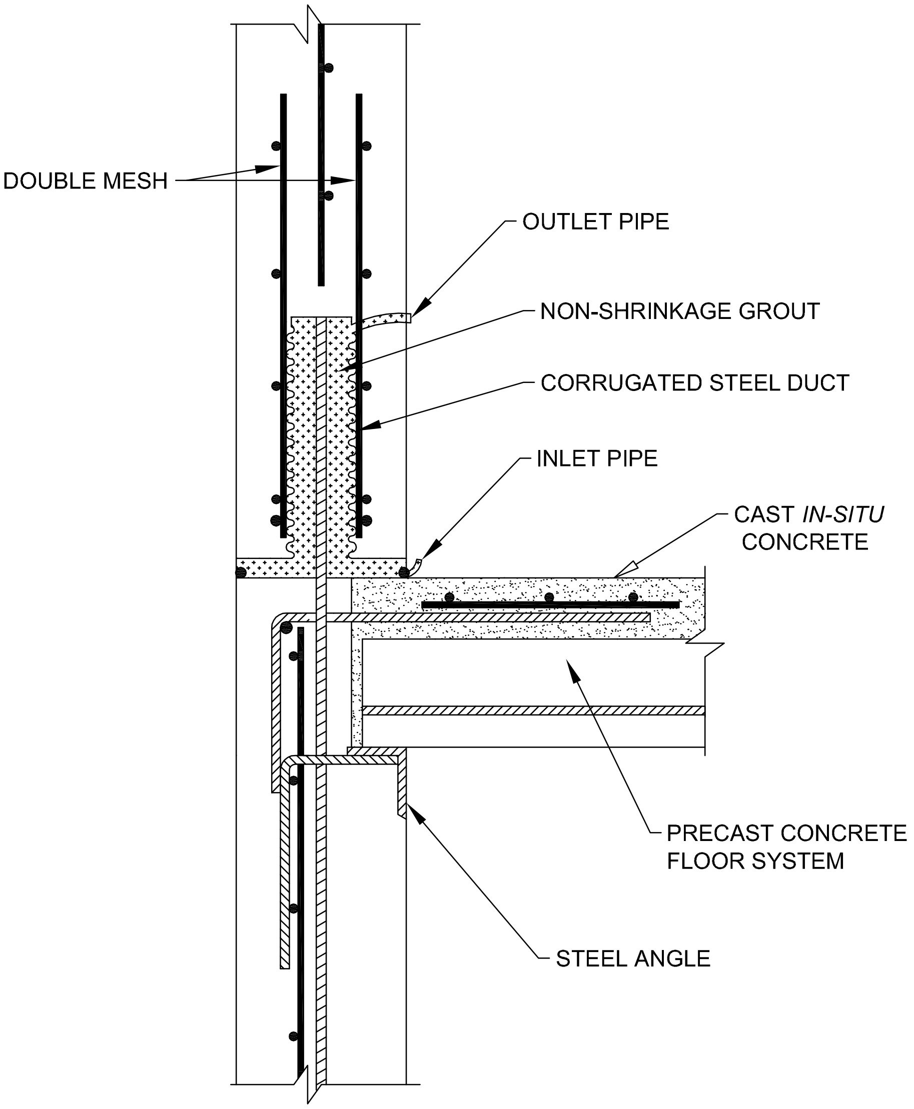
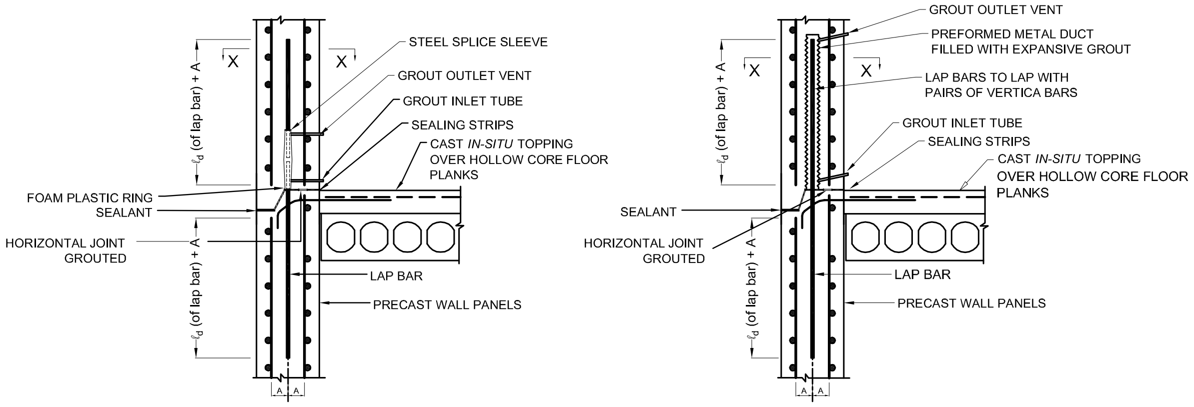
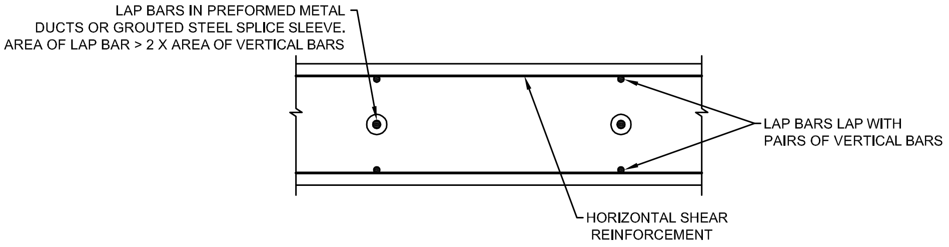


FIG. 25 EXTERIOR WALL-FLOOR SLAB CONNECTION DETAIL: PARTITIONED WALL WITH HORIZONTAL JOINT



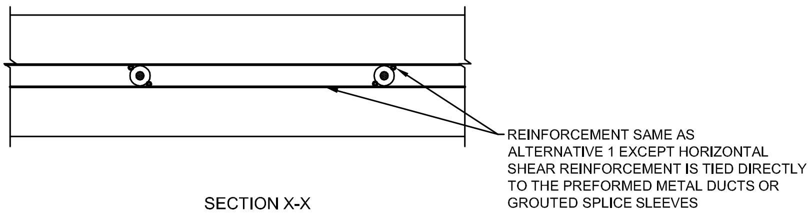
26A MONOLITHIC PRECAST CONCRETE WALL CONSTRUCTION HORIZONTAL JOINT - TYPE A

26B MONOLITHIC PRECAST CONCRETE WALL CONSTRUCTION HORIZONTAL JOINT - TYPE B


LAP BARS IN PREFORMED METAL DUCTS OR GROUTED STEEL SPLICE SLEEVE. AREA OF LAP BAR > 2 X AREA OF VERTICAL BARS
LAP BARS LAP WITH PAIRS OF VERTICAL BARS
HORIZONTAL SHEAR REINFORCEMENT

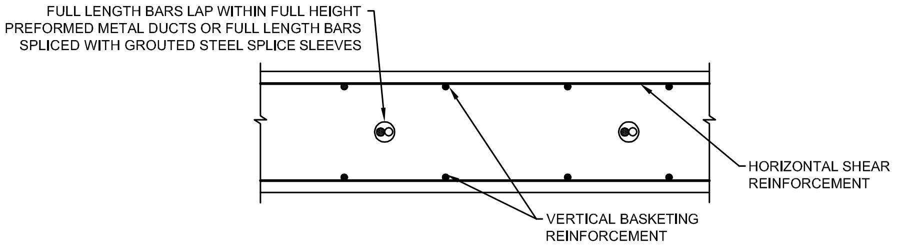
SECTION X-X

ALTERNATIVE 1


REINFORCEMENT SAME AS ALTERNATIVE 1 EXCEPT HORIZONTAL SHEAR REINFORCEMENT IS TIED DIRECTLY TO THE PREFORMED METAL DUCTS OR GROUTED SPLICE SLEEVES

SECTION X-X

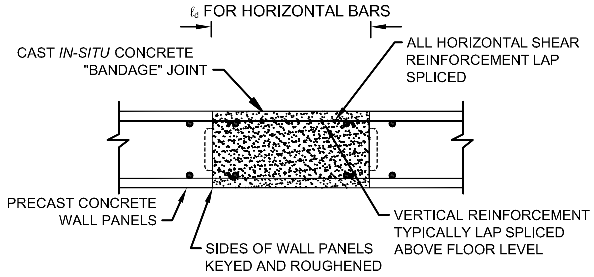
ALTERNATIVE 2


FULL LENGTH BARS LAP WITHIN FULL HEIGHT PREFORMED METAL DUCTS OR FULL LENGTH BARS SPLICED WITH GROUTED STEEL SPLICE SLEEVES
HORIZONTAL SHEAR REINFORCEMENT
VERTICAL BASKETING REINFORCEMENT

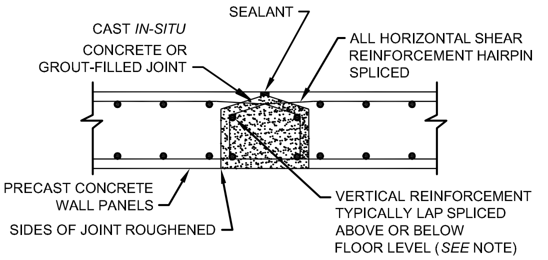
SECTION X-X

ALTERNATIVE 3

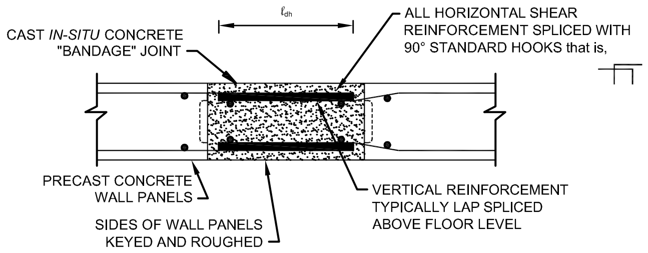
FIG. 26 MONOLITHIC PRECAST CONCRETE WALL CONSTRUCTION


ℓd FOR HORIZONTAL BARS
CAST IN-SITU CONCRETE "BANDAGE" JOINT
ALL HORIZONTAL SHEAR REINFORCEMENT LAP SPLICED
PRECAST CONCRETE WALL PANELS
VERTICAL REINFORCEMENT TYPICALLY LAP SPLICED ABOVE FLOOR LEVEL
SIDES OF WALL PANELS KEYED AND ROUGHENED

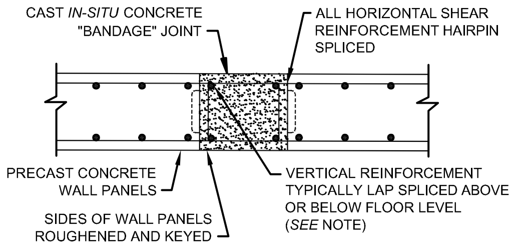
TYPE A


SEALANT
CAST IN-SITU CONCRETE OR GROUT-FILLED JOINT
ALL HORIZONTAL SHEAR REINFORCEMENT HAIRPIN SPLICED
PRECAST CONCRETE WALL PANELS
SIDES OF JOINT ROUGHENED
VERTICAL REINFORCEMENT TYPICALLY LAP SPLICED ABOVE OR BELOW FLOOR LEVEL (SEE NOTE)

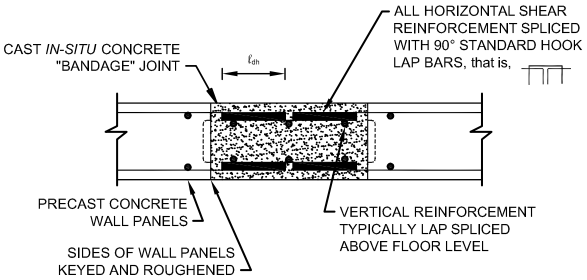
TYPE E


ℓdh
CAST IN-SITU CONCRETE "BANDAGE" JOINT
ALL HORIZONTAL SHEAR REINFORCEMENT SPLICED WITH 90° STANDARD HOOKS that is,
PRECAST CONCRETE WALL PANELS
SIDES OF WALL PANELS KEYED AND ROUGHED
VERTICAL REINFORCEMENT TYPICALLY LAP SPLICED ABOVE FLOOR LEVEL

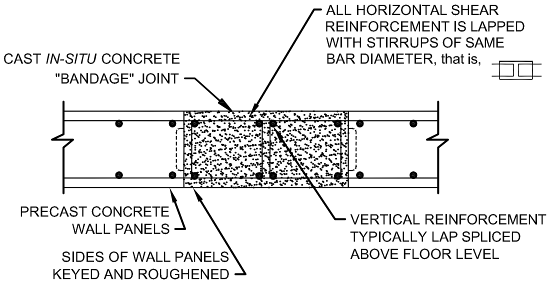
TYPE B


CAST IN-SITU CONCRETE "BANDAGE" JOINT
ALL HORIZONTAL SHEAR REINFORCEMENT HAIRPIN SPLICED
PRECAST CONCRETE WALL PANELS
SIDES OF WALL PANELS ROUGHENED AND KEYED
VERTICAL REINFORCEMENT TYPICALLY LAP SPLICED ABOVE OR BELOW FLOOR LEVEL (SEE NOTE)

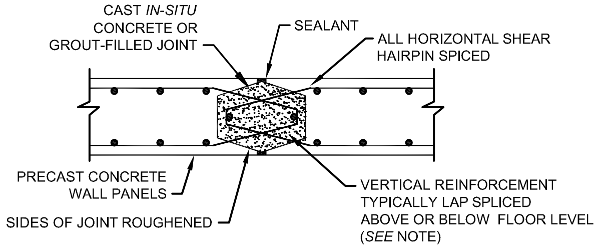
TYPE F


ALL HORIZONTAL SHEAR REINFORCEMENT SPLICED WITH 90° STANDARD HOOK LAP BARS, that is,
CAST IN-SITU CONCRETE "BANDAGE" JOINT
ℓdh
PRECAST CONCRETE WALL PANELS
SIDES OF WALL PANELS KEYED AND ROUGHENED
VERTICAL REINFORCEMENT TYPICALLY LAP SPLICED ABOVE FLOOR LEVEL

TYPE C


ALL HORIZONTAL SHEAR REINFORCEMENT IS LAPPED WITH STIRRUPS OF SAME BAR DIAMETER, that is,
CAST IN-SITU CONCRETE "BANDAGE" JOINT
PRECAST CONCRETE WALL PANELS
SIDES OF WALL PANELS KEYED AND ROUGHENED
VERTICAL REINFORCEMENT TYPICALLY LAP SPLICED ABOVE FLOOR LEVEL

TYPE G


CAST IN-SITU CONCRETE OR GROUT-FILLED JOINT
SEALANT
ALL HORIZONTAL SHEAR HAIRPIN SPICED
PRECAST CONCRETE WALL PANELS
SIDES OF JOINT ROUGHENED
VERTICAL REINFORCEMENT TYPICALLY LAP SPLICED ABOVE OR BELOW FLOOR LEVEL (SEE NOTE)

TYPE D

NOTE – Vertical joints shown as Types D, E and F need to be detailed with extreme care. Once the lapping bars have been overlapped, the ability for lowering the wall panels over starter bars is very restricted. These details will typical work only when grouted steel splice sleeves are used to splice the vertical flexural reinforcement and when the laps of the vertical bars in the "bandage" joints are made below floor level. Type D is not prefered because joint reinforcement and concrete infill cannot be inspected

FIG. 27 MONOLITHIC PRECAST CONCRETE WALL CONSTRUCTION VERTICAL JOINTS

ANNEX D

(*Foreword*)

COMMITTIEE COMPOSITION

Planning, Housing and Prefabricated Construction Sectional Committee, CED 51

Organization	*Representative(s)*
In Personal Capacity (*Isavasyam TC 18/1023, B-8/2, Lakshmi Nagar, Kesavadasapuram, Pottam P.O, Thiruvananthapuram 695 004*)	Shri V. Suresh (***Chairman***)
Army Welfare Housing Organization, New Delhi	Brig Pranv Dev Col Pankaj Mittal (*Alternate*)
B. G. Shirke Construction Technology Limited, Pune	Shri V. G. Jana Shri Yogesh P. Kajale (*Alternate*)
Bhardwaj Bhardwaj & Associates (P) Ltd, New Delhi	Shri A. Bhardwaj
Biltech Building Element Ltd, New Delhi	Shri Rajdeep Chowdhury Shri D. V. Kulkarni (*Alternate*)
Border Roads Organization, New Delhi	Shri A. P. Pittule
Building Materials and Technology Promotion Council, New Delhi	Dr Shailesh Kumar Agrawal
Central Government Employees Welfare Housing Organization, New Delhi	Shri Bhupinder Singh Shri M. Narayanan (*Alternate*)
Central Public Works Department, New Delhi	Shri Manu Amitabh Shri Divakar Agrawal (*Alternate*)
City and Industrial Development Corporation of Maharashtra Limited, Navi Mumbai	Shri S. K. Chotalia Dr K. M. Godbole (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Dr Ashok Kumar Shri S. K. Negi (*Alternate*)
CSIR-Structural Engineering Research Centre, Chennai	Dr J Prabhakar Dr P. Srinivasan (*Alternate*)
Delhi Development Authority, New Delhi	Engineer Member Commissioner (Planning) (*Alternate*)
Delhi State Industrial & Infrastructure Development Corporation, Delhi	Shri Bhavesh Gupta Shri Manish Sagar (*Alternate*)
Delhi Urban Shelter Improvement Board, New Delhi	Shri S. K. Mahajan Shri Jeet Ram (*Alternate*)
Department of Science & Technology, Ministry of Science & Technology, New Delhi	Dr Debapriya Dutta
Development Alternatives, New Delhi	Ms Zeenat Niazi Dr Soumen Maity (*Alternate*)
Engineering Consultants (India) Ltd, New Delhi	Shri Sukhbir Singh Mann Shri Aditya Sharma (*Alternate*)
Engineers India Limited, New Delhi	Shri Samir Das Shri Anish Kundu (*Alternate*)
G.B. Pant Institute of Himalayan Environment & Development, Almora	Shri Kireet Kumar Dr Varun Joshi (*Alternate*)
Himachal Pradesh Urban Development Authority, Shimla	Shri Dinesh Kashyap Shri Dewan C. Sharma (*Alternate*)
Hindustan Prefab Limited, New Delhi	Shri Rajesh Goel Shri S. K. Jain (*Alternate*)

Organization	*Representative(s)*
Housing and Urban Development Corporation Limited, New Delhi	Shri Akhilesh Kumar
Indian Green Building Council, Hyderabad	Shri M. Anand Shri Praveen Kumar Soma (*Alternate*)
Institute of Town Planners, India, New Delhi	Dr S. K. Kulshrestha
Larsen & Toubro Limited, Chennai	Shri K. P. Raghavan Shri S. Kanappan (*Alternate* I) Shri Amit Barde (*Alternate* II)
Military Engineer Services, Engineers- in-Chief’s Branch, Integrated HQ of MoD (Army), New Delhi	Shrimati Rivoo Mahendru Shri S. K. Mishra (*Alternate*)
Ministry of Housing & Urban Affairs, New Delhi	Shri D. S. Negi Shri Zile Singh Dishodia (*Alternate*)
Ministry of Rural Development, Govt of India, New Delhi	Representative
Mumbai Metropolitan Region Development Authority, Mumbai	Ms Uma Adusumilli Shri Vishran G. Patil (*Alternate*)
National Council for Cement and Building Materials, Ballabgarh	Shri B. P. Ranga Rao Shri Amit Trivedi (*Alternate*)
National Housing Bank, New Delhi	Shri K. Chakravarthy Shri Vishal Goyal (*Alternate*)
Nirman Vikas Anusandhan Sansthan, Raipur	Shri Alok Mahawar Shri Sanjeev Kasliwal (*Alternate*)
North Eastern Council, Shillong	Shri P. K. H. Singh Shri Doba Jini (*Alternate*)
School of Planning and Architecture, New Delhi	Dr P. S. N. Rao Dr Aruna R Grover (*Alternate*)
Shirish Patel and Associates Consultants Pvt Limited, Mumbai	Shri N. M. Ajugia Shri P. S. Badrinarayan (*Alternate*)
Tandon Consultants Pvt Limited, New Delhi	Shri Vinay Gupta Shri Praveen Kumar (*Alternate*)
Telangana State Housing Corporation Limited, Hyderabad	Shri Ch. Mallikarjuna Rao Shri P. Sriramulu (*Alternate*)
The Indian Institute of Architects, Mumbai	Shri Balbir Verma Shri Divya Kush (*Alternate*)
The Institution of Engineers (India), Kolkata	Representative
Town and Country Planning Organization, New Delhi	Shri R. Srinivas Shri Sudeep Roy (*Alternate*)
Ultratech Cement Ltd, Mumbai	Dr Venkatachalaiah Ramachandra Shri Srinivasa Govindappa (*Alternate*)
BIS Directorate General	Shri Sanjay Pant, Scientist ‘F’ and Head (Civil Engineering) [Representing Director General (*Ex-officio*)]

Member Secretary

Shrimati Madhurima Madhav

Scientist ‘D’ (Civil Engineering), BIS

(*Continued from second cover*)

s) Design considerations to minimize relative movements of precast components under loads have been provided.

t) Provisions on site prefabrication have been updated.

u) Provisions on stacking and transportation of precast elements have been updated.

v) Provisions on load test of individual components have been modified.

w) Provisions for erection have been updated, and associated design considerations have been included.

y) Annex B has been included on common defects, their causes and remedies which cover dimensional deviations, cracks, honeycombing, damages, strand slippage, alignment, etc.

z) Typical figures of some of the common precast joint connections have been provided.

Prefabricated constructions being comparatively a new technique, some of the essential requirements for the manufacture of the prefabricated components and elements are also included in this standard.

In this standard, an attempt has been made to prescribe general requirements applicable to all valid existing systems using prefabricated concrete as also to accommodate any new such system introduced in the country in future.

The design of prefabricated buildings shall include provision for all installations of services and their required piping, wiring and accessories to be installed in the building.

Annex B provides information relating to common defects and remedies relating to prefabricated concrete construction.

A separate Indian Standard IS 15917 : 2020 'Building design and erection using mixed/composite construction — Code of practice (*first revision*)' exists, for those systems approach which uses mixed/composite construction.

The composition of the technical Committee responsible for formulation of this standard is given in Annex D.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 2016 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in the course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Director (Publications), BIS.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards: Monthly Additions'.

This Indian Standard has been developed from Doc No.: CED 51 (12230).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.gov.in

Regional Offices:		*Telephones*
Central	: Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110002	2323 7617 2323 3841
Eastern	: 1/14 C.I.T. Scheme VII M, V.I.P. Road, Kankurgachi KOLKATA 700054	2337 8499, 2337 8561 2337 8626, 2337 9120
Northern	: Plot No. 4-A, Sector 27-B, Madhya Marg CHANDIGARH 160019	265 0206 265 0290
Southern	: C.I.T. Campus, IV Cross Road, CHENNAI 600113	2254 1216, 2254 1442 2254 2519, 2254 2315
Western	: Manakalaya, E9 MIDC, Marol, Andheri (East) MUMBAI 400093	2832 9295, 2832 7858 2832 7891, 2832 7892

Branches : AHMEDABAD. BENGALURU. BHOPAL. BHUBANESHWAR. COIMBATORE. DEHRADUN. DURGAPUR. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. JAMMU. JAMSHEDPUR. KOCHI. LUCKNOW. NAGPUR. PARWANOO. PATNA. PUNE. RAIPUR. RAJKOT. VISAKHAPATNAM.

Published by BIS, New Delhi